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ABSTRACT

This training manual is designed to lay the foundation for trainers and technicians by showing the steps to achieve and maintain good indoor air quality through use of cleaner-burning forklifts and materials handlers. The first part of the manual consists of nine units that provide informational material and diagrams on these topics: comparison of gaseous fuels to gasoline; fuel system operation; propane tanks; compressed natural gas (CNG) cylinders; fuel system components; health and safety; fueling; maintenance and repair; and exhaust emissions. A glossary is provided. The second part of the manual contains a suggested agenda for a 2-day course covering the material. A one-page lesson plan called instructor notes is provided for each unit as well as the following: introductions, pretests, definitions, summary and discussion, posttest, feedback and evaluations, and fast-breaking news. Instructor notes follow this format: time for the section, section title, objectives, content sequence, and media materials needed. The third part of the manual contains student activity sheets in this format: places for student name and date; objective; equipment required; safety requirements; procedure; and any necessary material. The final section consists of the pretest and posttest and answer sheets for the two tests. (YLB)

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ED 421 623

Heavy Duty and Industrial Alternative Fuel Applications Forklift and Material Handling

Alternative Fuels Training
May 1997

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ACKNOWLEDGEMENTS

The Forklift and Material Handling Manual is the compilation of research and cooperation between individuals, industry, academia, and government organizations. To accomplish the final manual, three national conferences were held across the United States in order to receive input and suggestions.

The first was held in Nashville, TN. In Nashville, the project coordinators heard from representatives of industry, government, and academia regarding the concern for the environment, public health, and economic development. The result of this first meeting were the audience analysis and the definition of the objectives needed to develop the manual.

The second was held in Chicago, Illinois. In Chicago the project coordinators verified the audience analysis, and reviewed the objectives of the manual. The next step was the development of the content outline and the development of content examination questions.

The third conference was held at Hilton Head, South Carolina. At Hilton Head, the project coordinators presented the finished product to the participants. The participants reviewed the manual for technical accuracy and clarity. Activities to enhance learning and job aids were designed, and approved.

Numerous meetings with individual subject matter experts then took place to clarify extremely technical areas to ensure clarity and accuracy.

Project Coordinators:

Doug Eckert
Lori Casto

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VERSION 2.0

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INTRODUCTION

Need for Cleaner Burning Fuels

Society is becoming increasingly worker oriented. Efforts to improve indoor air quality (IAQ) have prompted many businesses to switch indoor vehicles to cleaner burning fuels. The focus on worker comfort, health, and overall safety are at an all-time high in many industrialized countries. Working environments are striving to comply with federal and local environmental health standards. Clearly, there is also an economic incentive for business owners to cleanup their factories. In the United States, for example, the Environmental Protection Agency (EPA), the Occupational Health and Safety Administration (OSHA), and other government agencies have issued more stringent air-quality standards and have not hesitated to levy hefty fines on businesses that fail to comply. This is a major reason why cleaner-burning forklifts and materials handlers have become a high priority for many corporations (Figure 1.1).

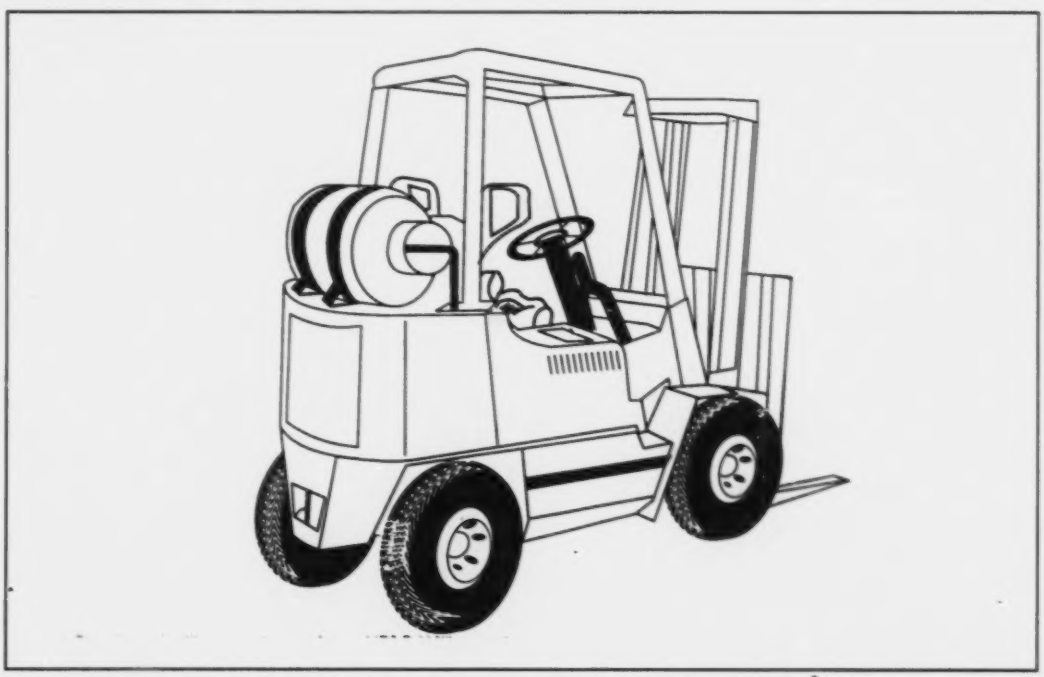

Figure 1.1 CNG Fueled Forklift

INTRODUCTION

Concern for the environment has moved indoors! Throughout North America and around the world millions of vehicles operate in these indoor environments with a single overriding purpose – to keep the wheels of business spinning. The most prevalent of these indoor vehicles are forklifts, lifting and carrying devices which enable manufacturing facilities and companies of all types to move products from point to point. The Gas Research Institute estimates that there are currently (1997) over 1.3 million lift trucks in active service in this country alone. Today, a high percentage of all forklifts are powered by liquid petroleum gas (propane) and compressed natural gas (CNG). While both fuels are capable of producing low exhaust emissions and offering other benefits, neither can be used as the sole means for achieving acceptable air quality standards, without proper maintenance and adjustments to the systems. The purpose of the following training material is to lay the foundation for trainers and technicians by showing the steps to achieve and maintain good indoor air quality.

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COMPARISON OF GASEOUS FUELS TO GASOLINE

It is important to understand the characteristics of each of the alternative fuels that may be encountered. The nature of the fuel causes corresponding changes in the combustion process within the engine. Alternative fuels vary in their physical nature, from a liquid to a vapor. In order to start from a common baseline in this course, the important terms and concepts will be discussed. When propane or natural gas is used as an engine fuel, it is quite common for an untrained technician to misdiagnose an ignition problem as a fuel problem, especially with bi-fueled engines.

Ignition

As previously stated, the use of alternative fuels in engine applications requires an understanding of the process of combustion within the combustion chamber; but first lets review how a simple ignition system functions (Figure 2.1).

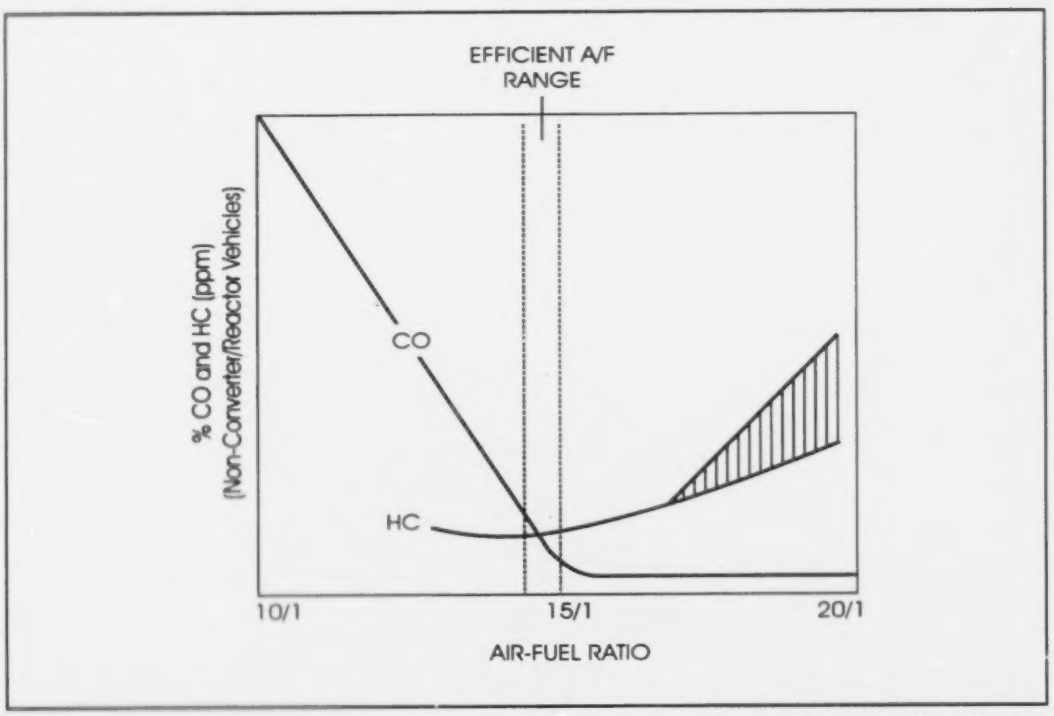

Figure 2.1 Basic Ignition System

COMPARISON OF GASEOUS FUELS TO GASOLINE

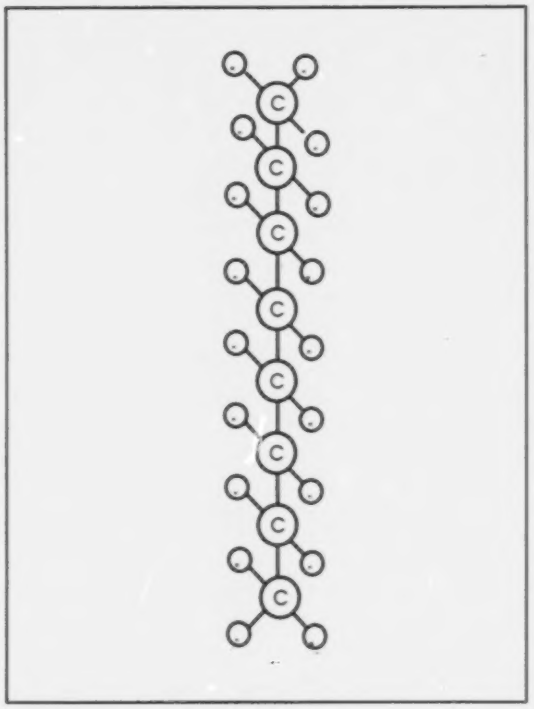

Figure 2.2 Gasoline Molecule

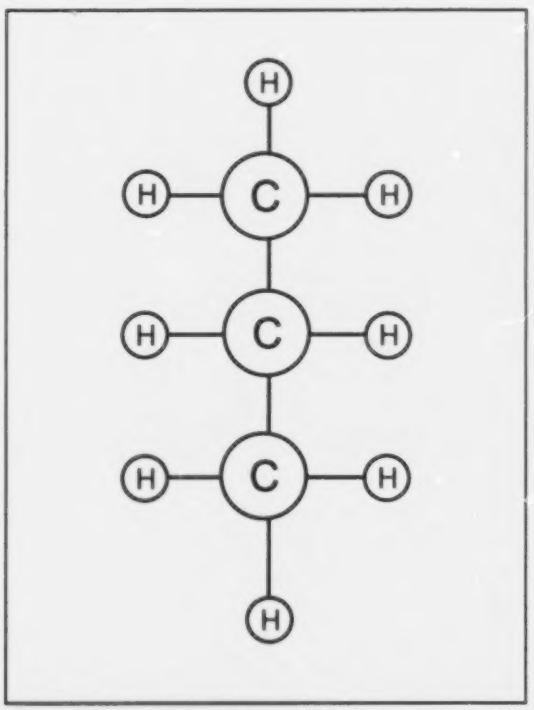

Figure 2.3 Propane Molecule

A typical spark plug design consists of an insulated electrode and a ground. To cause a spark to cross from the electrode to the ground requires a certain amount of electrical energy.

The energy comes from the ignition coil and through the distributor to the wires. The energy from the collapsing coil induces a voltage into the secondary windings. The voltage then is transferred through a single high tension carbon wire to the distributor cap.

The electrical energy is routed via the rotor to the appropriate high tension carbon wire to the spark plug. A metal connector connects the plug wire to the spark plug, allowing the electrical energy to flow down the insulated electrode. If there were only atmospheric air in the combustion chamber, the spark would jump across to ground; but because the air is compressed by the rising piston on the compression stroke, the spark will not jump because the resistance is too great. This is where fuel composition becomes important.

In order for the electrical energy to reach ground, a conductor is needed. If some form of carbon is placed between the electrode and the ground, the energy can then freely dissipate. A source of carbon is found in the carbon content of fuel (Figure 2.2).

Each molecule of fuel (propane, for example) contains hydrogen and carbon (Figure 2.3). Carbon is a good conductor of electricity.

The carbon in the fuel becomes a bridge for the electrical energy to jump the spark plug gap. The energy will cross the gap as long as there is sufficient carbon (fuel) in the air mixture (Figure 2.4).

COMPARISON OF GASEOUS FUELS TO GASOLINE

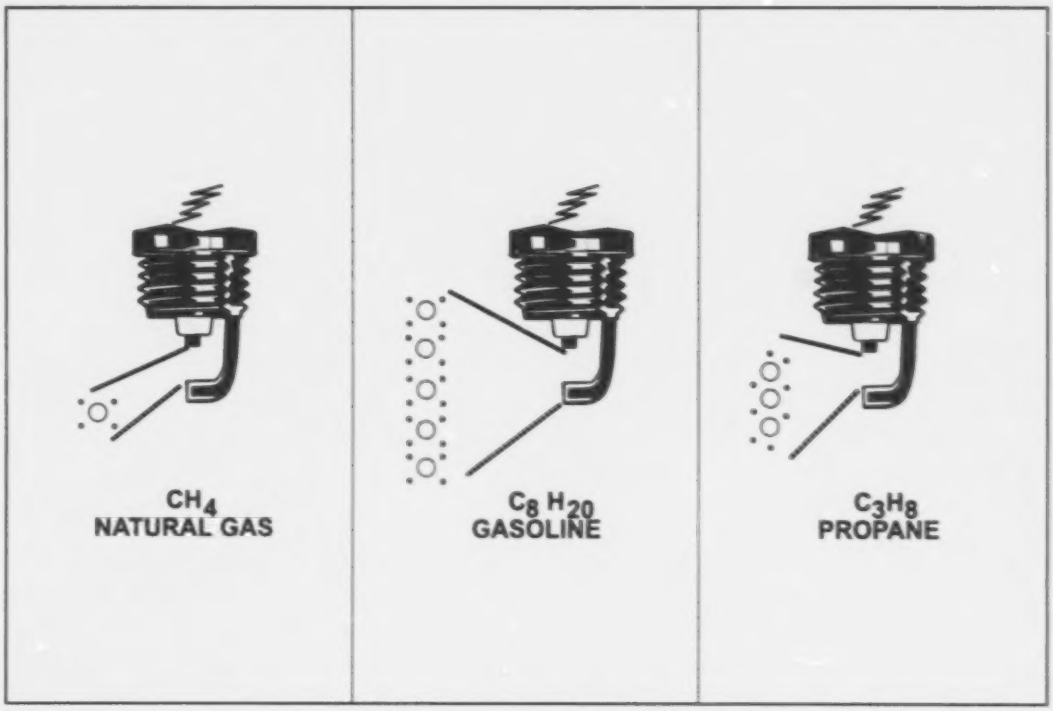

Figure 2.4 Spark Plug and Fuel Characteristic

Air/Fuel Mixtures

When fuel is introduced into the air flowing to the combustion chamber, the resultant air/fuel mixture takes on a different characteristic from air alone. The mixture becomes a conductor. The electrical circuit has the possibility of being completed, as long as the air/fuel mixture is correct. Lean air/fuel mixtures are difficult to ignite. For example, an engine will backfire into the intake manifold when air/fuel mixtures are too lean; there is not sufficient electrical energy to jump the spark plug gap so the energy will take the path of least resistance and jump to a cylinder that has an intake valve open, thus causing the backfire.

The type of fuel is an important consideration. A gasoline air/fuel mixture that allows a spark to bridge the gap may not have sufficient electrical energy to bridge the same gap when using propane or natural

gas as a fuel, simply because the carbon content has been changed. Propane and natural gas have less carbon content than gasoline. The carbon content in each of the alternative fuels is different, and understanding this difference will enable one to understand how each fuel's characteristics affect the combustion process. The base fuel that is commonly used as a reference measure for other fuels is indolene (A special gasoline used in testing emissions).

Molecular Structure

The molecular structure of a fuel determines the amount of hydrocarbons available for combustion. A low carbon content fuel requires more electrical energy to ignite the air/fuel mixture. In a fuel with a low carbon to hydrogen ratio, the potential exists to produce low carbon monoxide (CO) and less smog reactive hydrocarbons in exhaust emissions.

The safety of a fuel can be asso-ciated with the state it is in. Gaseous fuels do not puddle on the ground if a leak occurs. Gaseous fuels provide good cold-weather starting characteristics, unlike liquid fuels, and have the potential to reduce engine maintenance (less carbon deposits, less lubrication oil degradation). Gaseous fuels displace engine intake air volume, and a loss of power in an Otto cycle (spark-ignited) engine will occur if no modifications are made (e.g., using higher compression ratios).

Stored State

The storage of alternative fuels for use in engine applications is a consideration, and may be the determining factor when deciding which alternative fuel to use. Liquid fuels require less storage space than gaseous fuels. The added weight and space of fuel storage containers can be considerable (Figure 2.5).

COMPARISON OF GASEOUS FUELS TO GASOLINE

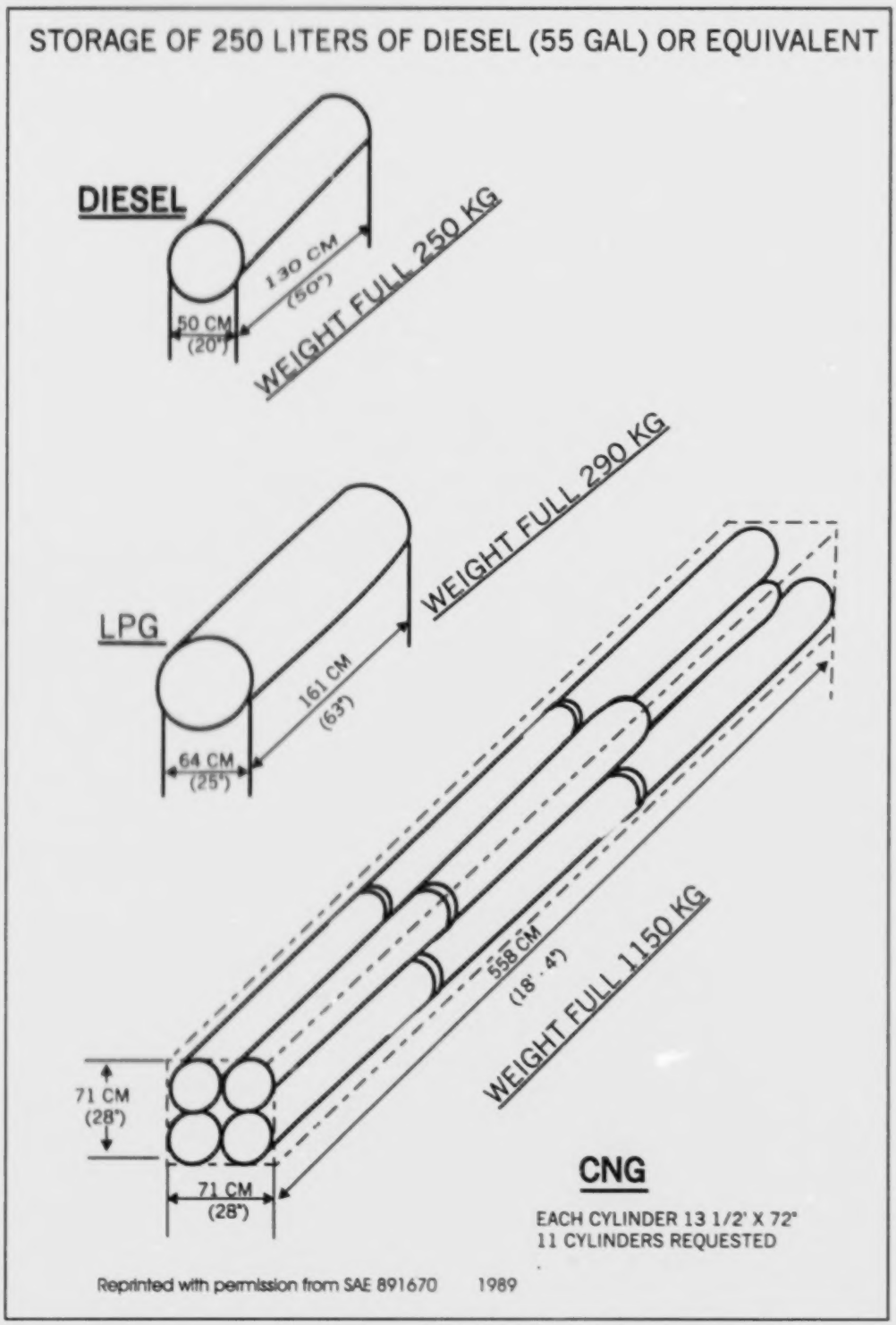

Figure 2.5 Tank Equivalents

COMPARISON OF GASEOUS FUELS TO GASOLINE

Boiling Point

The boiling point of fuels is an important characteristic of the combustion process. The temperature at which a fuel changes from a liquid to a vapor is a factor that determines engine cold-weather starting and operating. The lower the temperature at which a fuel vaporizes, the easier the engine will start. This is because of the ability of the air/fuel mixture to thoroughly mix before being ignited in the combustion chamber (Figure 2.6).

Vapor Density

Vapor density is the weight of a gas in relation to air. The density of the fuel vapor determines if the fuel will rise or fall, if a leak occurs. This is an important safety feature that technicians need to be aware of

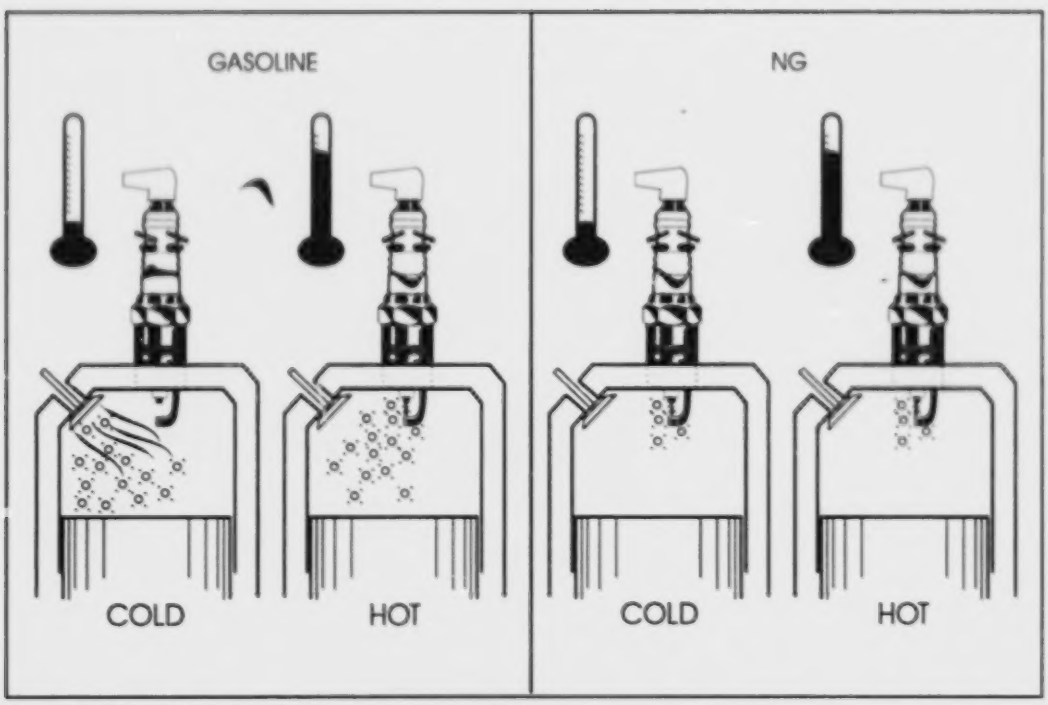

Figure 2.6 Fuel Characteristic and Spark Plug Effect

COMPARISON OF GASEOUS FUELS TO GASOLINE

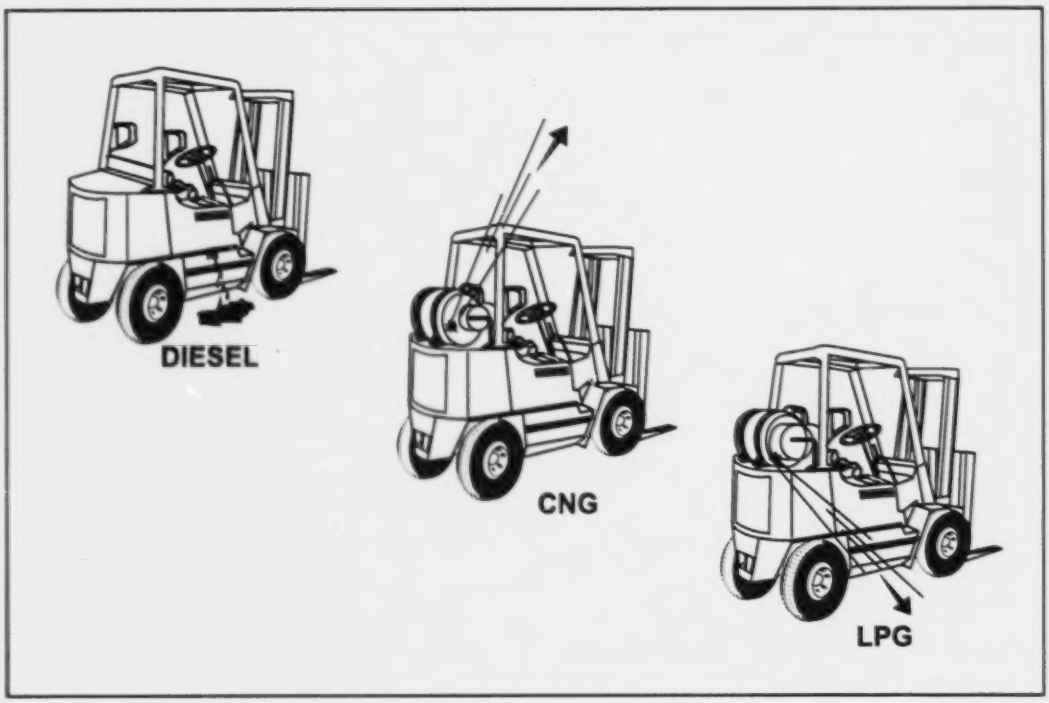

Figure 2.7 Fuel Property

when performing maintenance. Fuels that have a lighter than air vapor density will tend to have the vapor rise and collect in building ceilings and rafters. Fuels that have a heavier than air vapor density will tend to have the vapor collect in the low-lying areas. Fuels that have a low vapor density also tend to require a larger storage space (Figure 2.7 and Fuel Chart).

Energy Density

The energy density of a fuel is a measure of the energy content of a specific fuel for a given volume. Energy density is used for comparing similar quantities of fuel to the amount of energy released in a complete combustion process. This is usually expressed in pounds per horsepower hour of the fuels (Fuel Chart).

COMPARISON OF GASEOUS FUELS TO GASOLINE

Flash Point

The flash point of a fuel is the lowest temperature at which a fuel will emit a vapor that can be ignited by an ignition source. This is a feature of fuels to be considered during maintenance and fueling operations (Fuel Chart).

Flammability Limits

Flammability limits is the minimum or maximum percentage of fuel needed in an air/fuel mixture, as measured by volume, to support combustion. Flammability limits play a role in two areas: (1) How lean or rich a air/fuel mixture can be before misfire occurs and (2) Safety. The higher the flammability limit, the higher the safety margin required in handling the fuels. A fuel that has a low flammability limit only requires a small amount of fuel to leak in order to support combustion. A fuel that requires a larger ratio of air/fuel mixture will, if a leak occurs, be easier to detect before ignition (Fuel Chart).

Octane Number

The octane number of a fuel is the measurement of the fuels anti-knock characteristic. Knock is the autoignition of the end gas in a combustion chamber. Low octane fuels are prone to autoignition. Fuels with high octane numbers generally permit higher compression ratios and turbo boost pressures than do fuels with low octane numbers (Fuel Chart).

Cetane Number

The cetane number is an indicator of the ignition quality of a diesel fuel. The higher the cetane number of a fuel, the easier it is to ignite. The higher the cetane number, the shorter the delay between injection and ignition in the combustion chamber (Fuel Chart).

COMPARISON OF GASEOUS FUELS TO GASOLINE

Auto Ignition Temperature

The auto ignition temperature (the temperature at which a fuel self-ignites) is important for knock and detonation considerations. Lower auto-ignition temperatures will permit knock and detonation to readily occur (Fuel Chart).

Propane

Propane can come from two sources: (1) it can be stripped from natural gas, or (2) it can be obtained from crude oil as part of the oil refining process. Propane, like gasoline, is a compound of hydrogen and carbon, commonly called hydrocarbons. A major difference between the two fuels is that propane remains in a vapor state under normal atmospheric conditions, whereas gasoline remains in a liquid state under similar conditions.

Propane, when moderately compressed, changes to a liquid state; e.g., at 70 degrees F. It takes 110 psig. to liquefy. The pressure required to liquefy propane varies according to ambient temperature. In its natural state, propane is colorless and odorless; an odorant (mercapton) is added to the fuel so its presence can be detected. Propane vapor has a high specific gravity — it is heavier than air. Because propane has a low boiling point (-44 F.), and is a low carbon fuel, engine life can be extended due to less cylinder wall wash down and little if any carbon build up. In most instances, oil change periods can be extended.

Compressed Natural Gas

Natural gas is a naturally occurring gas that is normally delivered via a pipeline to the end user. Unlike propane, it does not liquefy when compressed. To liquefy natural gas, it has to be refrigerated to -260° F and then

stored in a LNG tank that is similar in design to a thermos flask. To have sufficient volumetric storage capacity, natural gas is compressed 3,000 to 3,600 psig in the fuel storage cylinder. Like propane, natural gas is colorless and odorless, so an odorant is added to the fuel to detect its presence. In its gaseous state, it is lighter than air. Natural gas offers similar benefits to engine life and maintenance as does propane and can produce exhaust CO levels slightly lower than propane when fuel mixtures are set in the engine for best torque output. Natural gas displaces a little more of the incoming air than does propane, resulting in slightly lower horsepower production.

FUEL SYSTEM OPERATION

Carburetion

The majority of gasoline fuel systems in use in the material handling field still use carburetors. So before studying how gaseous fuel systems function, the function of the gasoline carburetor will be reviewed (Figure 3.1). Carburetors, mechanical fuel injection systems, and electronic fuel injection systems all perform the same basic functions; however, the methods incorporated to perform these functions differ. The fundamental purpose of any fuel system is to measure the incoming air mass and mix the appropriate amount of fuel with it, under all engine operating conditions. This applies equally to gasoline or gaseous fuel systems. The basic engine operating conditions have not changed much over the years. What has changed is the government and consumer outlooks concerning lower exhaust gas emissions, improved fuel economy, and efficient energy usage and conservation.

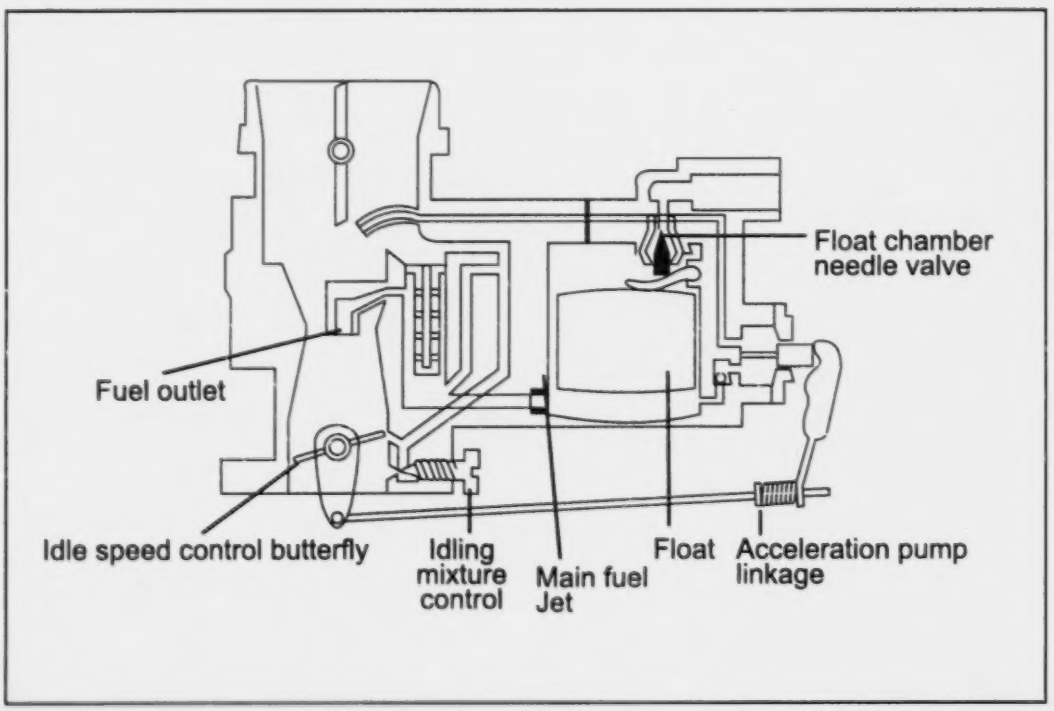

Figure 3.1 Carburetor Cutaway

Engine Operating Requirements

Engine operating requirements may be described as 7 circuits:

1. cold start
2. fast idle
3. steady idling when engine is hot
4. progression off idle
5. cruise or light throttle
6. wide open throttle (full power)
7. acceleration

The Gasoline Carburetor

The carburetor performs three main functions. These functions include:

1. delivering a mixture of gas and air in a ratio that suits each condition of engine operation,
2. atomizing the gasoline as it enters the intake manifold, and
3. controlling the volume of air/fuel delivered in response to throttle position and engine operation condition.

In reality, each engine operating condition requires a circuit or mechanism to be designed into/or attached to the gasoline carburetor. This ensures that the engine will operate without hesitation or "flat-spot" and give maximum power with the optimum fuel economy within the levels of emissions for that model and year of engine design.

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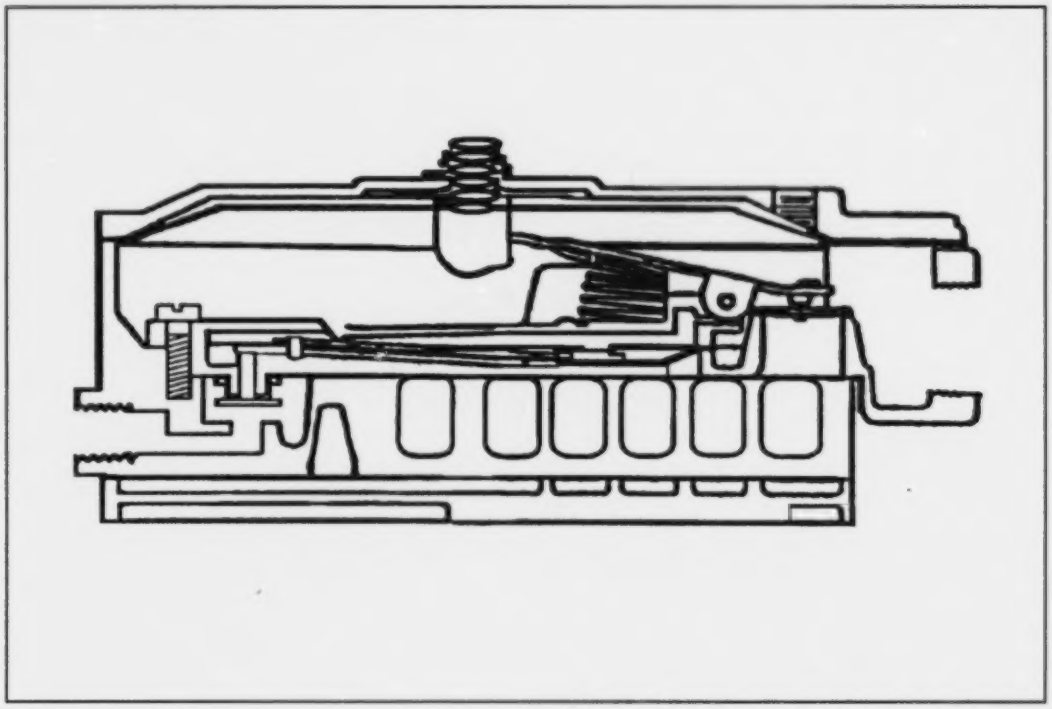

Figure 3.2 Gaseous Fuel Mixer Cross Section

Gaseous Fuel System Operation

The major components of a gas system are separated throughout the engine compartment rather than in a one-piece casting, such as is in a gasoline carburetor. For example, a gas/air mixer performs the same function as a carburetor venturi and discharge nozzle. A gaseous fuel system performs the same functions as a gasoline fuel system. However, there are important differences between the two. The primary side of the gas regu-lator (Figure 3.2) acts as the system fuel pump and the secondary side serves the same function a float chamber and inlet needle and seat. The size of the passageways and jets are much larger because we are dealing with a gas and not a liquid fuel.

Operational Sequences of a Propane Fuel System:

1. Liquid propane, at approximately 100 psi, flows from the tank through the service line to a bulkhead filter. Usually a hydrostatic relief valve is located in the bulkhead. Its function is to relieve pressure 400-500 psi that could occur if the liquid in the service line were to be heated by a fire, etc.

2. From the bulkhead, fuel flows through a shutoff valve, commonly known as a "lock off"; this device prevents fuel from flowing to the rest of the system unless it is activated by either manifold vacuum or an ignition source.

3. From the shutoff valve, fuel enters the vaporizer regulator (converter), gas pressure is reduced to at or near "0" water column WC and is vaporized from a liquid state. Engine coolant flows through this device to aid fuel vaporization; it then enters the gas air mixer to be mixed with the incoming air ready for combustion (Figure 3.3).

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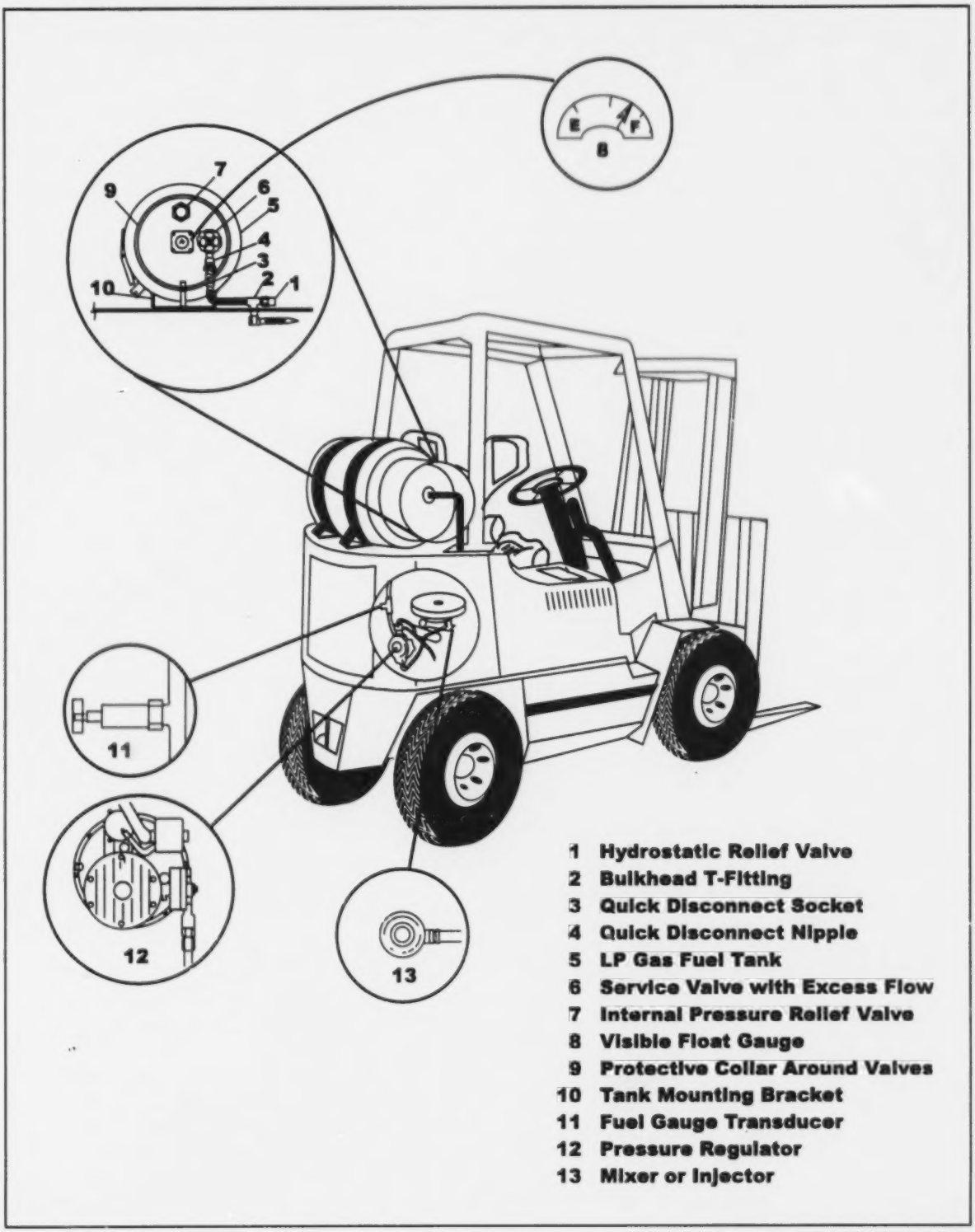

1 Hydrostatic Relief Valve
2 Bulkhead T-Fitting
3 Quick Disconnect Socket
4 Quick Disconnect Nipple
5 LP Gas Fuel Tank
6 Service Valve with Excess Flow
7 Internal Pressure Relief Valve
8 Visible Float Gauge
9 Protective Collar Around Valves
10 Tank Mounting Bracket
11 Fuel Gauge Transducer
12 Pressure Regulator
13 Mixer or Injector

Figure 3.3 Propane Fuel System

Operational Sequences of a CNG Fuel System:

1. Compressed natural gas flows from the tank through the service line to a bulkhead connection and into a high pressure regulator where gas pressure is reduced to approximately 125 psi. Usually there is a Hydrostatic relief valve in the regulator. Its function is to relieve pressure above 450 psi that could occur if there is a failure in the seat area of the regulator. The High Pressure Regulator has engine coolant flowing through it to prevent freezing due to the refrigerant action caused by the large pressure drop in this device.

2. From the High Pressure Regulator, fuel flows through a shutoff valve, commonly known as a "lockoff"; this device prevents fuel from flowing to the rest of the system, unless it is activated by either manifold vacuum or an ignition source.

3. From the shutoff valve, fuel may enter a final stage regulator where pressure is further reduced and then enters the gas/air mixer to be mixed with the incoming air ready for combustion. It may have a multistage regulator where pressure is reduced to a little above ambient pressure through multiple pressure drops. The multistage regulator may be designed as a single unit (Figure 3.4).

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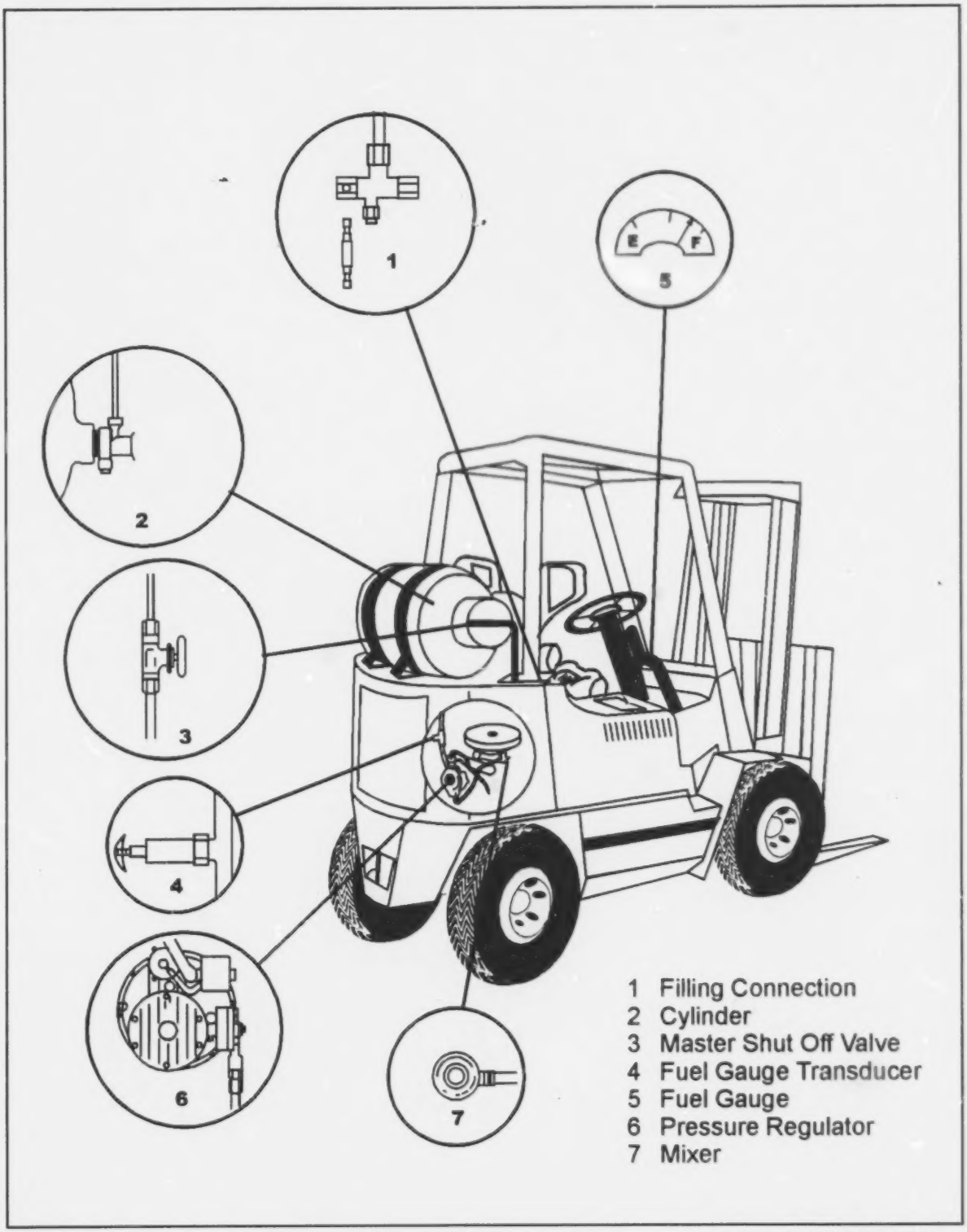

Figure 3.4 CNG Fuel System

PROPANE TANKS

Design and Construction

Propane Tank design and operation is fairly similar world wide, although construction and material standards differ from country to country. In the USA, tanks must be designed, fabricated, tested, marked and certified to meet the codes and standards of the US Department of Transportation (DOT) or The American Society of Mechanical Engineers (ASME). Under no circumstances should any container be filled with propane that does not conform to these codes and standards.

Propane tanks are designed to be filled to a maximum of 80 percent of capacity; this leaves 20 percent of the capacity available for vaporized propane gas. The purpose of this is to give the liquid room for expansion, if there is an increase in temperature. If the tank is overfilled, and not enough room is left for expansion, the pressure will increase to the point where the relief valve will open, exhausting liquid propane. Any time the relief valve opens on a propane tank, the tank must be taken outdoors and away from buildings and the propane supplier notified.

One cup of liquid propane expands to 270 cups of vapor. Mixing 24 parts air to 1 part fuel will create a large pocket of ignitable fuel. Propane expands $1^{1/2}$ percent in volume for every 10 degrees of temperature (Figure 4.1). If the tank is filled to 80 percent of volume and the temperature climbs from 0 degrees to 50 degrees, the tank will be 87.5 percent full. If a tank is in a fire, the pressure will expand and the relief valve will exhaust propane. If ignited, propane will burn. However, the tank will not explode because there is no oxygen in the tank to support combustion. If water is directed on the tank to cool it, the pressure will drop, the relief valve will close, and the flame will extinguish.

There are two methods employed in supplying propane to a engine: (a) "vapor

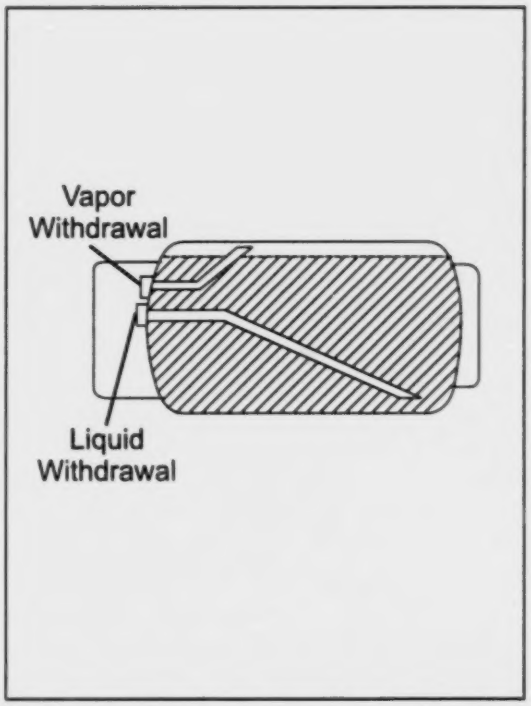

Figure 4.1 Propane Tank with Tubes

withdrawal" and (b) "liquid withdrawal." The vapor withdrawal method is common on air cooled engines up to about 25 hp. Fuel is drawn from the vapor space in the tank directly to the regulator. The size of the tank and the ambient temperature affect how much propane gas is available to the engine from the vapor space in the tank. In the "liquid withdrawal" method of fuel withdrawal, liquid fuel is forced from the container by the vapor pressure in the tank. The liquid is turned into a gas at the vaporizer regulator (converter). This method ensures that an adequate supply of fuel is available for the engine demand regardless of the tank size or temperature.

The ASME tank is designed to be a permanently mounted tank. It is built to the standards set by NFPA 58. The tank must be able to withstand four times its working pressure. The working pressure determines the type of relief valve. Either a 250 psig or a 312 psig relief valve is used on an ASME tank. A 375 psig relief valve is used on a forklift tank (Figure 4.2).

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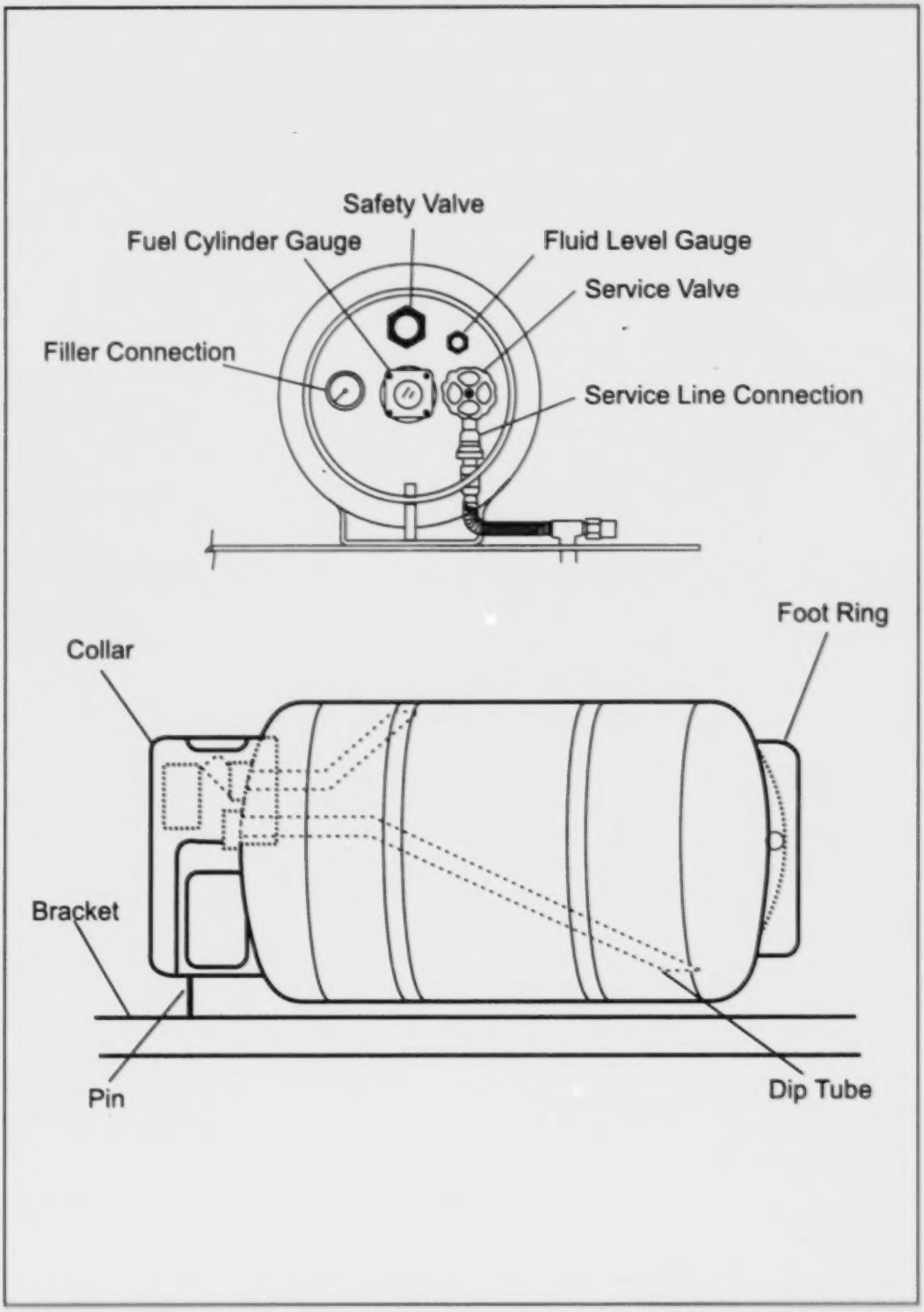

Figure 4.2 Fuel Cylinders for Forklift Trucks

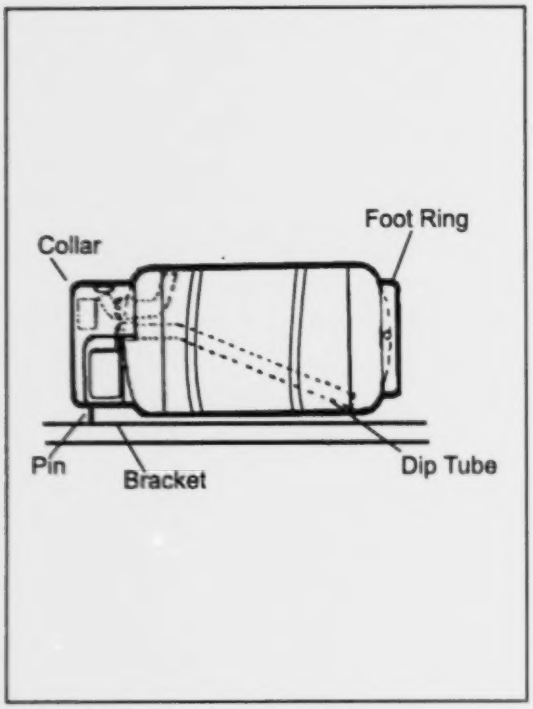

Figure 4.3 Fuel Cylinder for Lift Trucks

ASME tanks or containers must be constructed for a minimum 250-psi (1.7-mPa) design pressure. The only exception is when containers are installed in enclosed spaces on vehicles. This type of engine fuel container can be used for industrial lift trucks, but is normally used in trucks, buses (including school buses), and multipurpose passenger vehicles. When used here, they must be constructed to a design pressure of at least 312.5 psig (92.1 mPa) (Figure 4.3).

The DOT tank does not have an attached information plate like the ASME tank. The information is stamped into the collar of the DOT tank. The ASME tank does not require any retesting or recertification; the DOT tank does. The DOT tank must be recertified with a visual inspection after the first 12 years. Following the first 12 years, if the tank is hydrostatically tested, it must be recertified every 7 years thereafter. If the tank is visually tested, the tank must be recertified every 5 years thereafter. Test dates and the letter indicating the type of test done must be imprinted on the tank collar. The relief valve must be replaced with a new valve after the first 12 years and every 10 years thereafter.

The tank must be discarded if the collar is damaged to the point that it can no longer protect the valves. It must also be replaced if the foot ring is bent to the point where the tank will not stand or is easily knocked over. When installing a tank on a lift truck, the tank must be within the outline of the vehicle. This will ensure that the tank will not hit objects when maneuvering in tight places, preventing damage to the tank or its valves.

Installing Tanks

The DOT tank is the tank most commonly used on forklifts. The tank may be installed in a vertical or a horizontal position. When empty, this tank is exchanged with a

prefilled replacement tank. When exchanging a tank, safety glasses and gloves should be worn. The replacement tank must be installed on the saddle which contains a protruding pin which matches a hole in the collar of the tank. When the pin is in the hole, the liquid withdrawal tube is positioned to the bottom. When this tank is in horizontal position, this tube is also bent to a downward position to that of the tank. A common problem is that a lot of these guidepins are broken off, allowing the tank to be mounted in any position. This creates two problems. One, when the liquid withdrawal tube is exposed to the vapor space, it may give a false indication that the tank is empty, when it actually is not. Two, the safety relief valve may be immersed in liquid fuel. If for any reason the valve has to vent, venting liquid can cause a serious safety problem.

When mounted In a vertical position, liquid will travel up the liquid withdrawal tube from the bottom of the tank regardless of tank orientation in the tank cradle.

The tank must be securely mounted in its brackets. The brackets of both ASME and DOT tanks must be able to support and secure four times the combined weight of the tank and the fuel.

Decals

There are two main decals required on DOT cylinders.

Name:	OSHA propane decal
Form no:	wl-701, item #1000788
Description:	decal, 3" x 6" black letters on white
Use:	affix to all containers used on commercial-industrial applications (Figure 4.4).

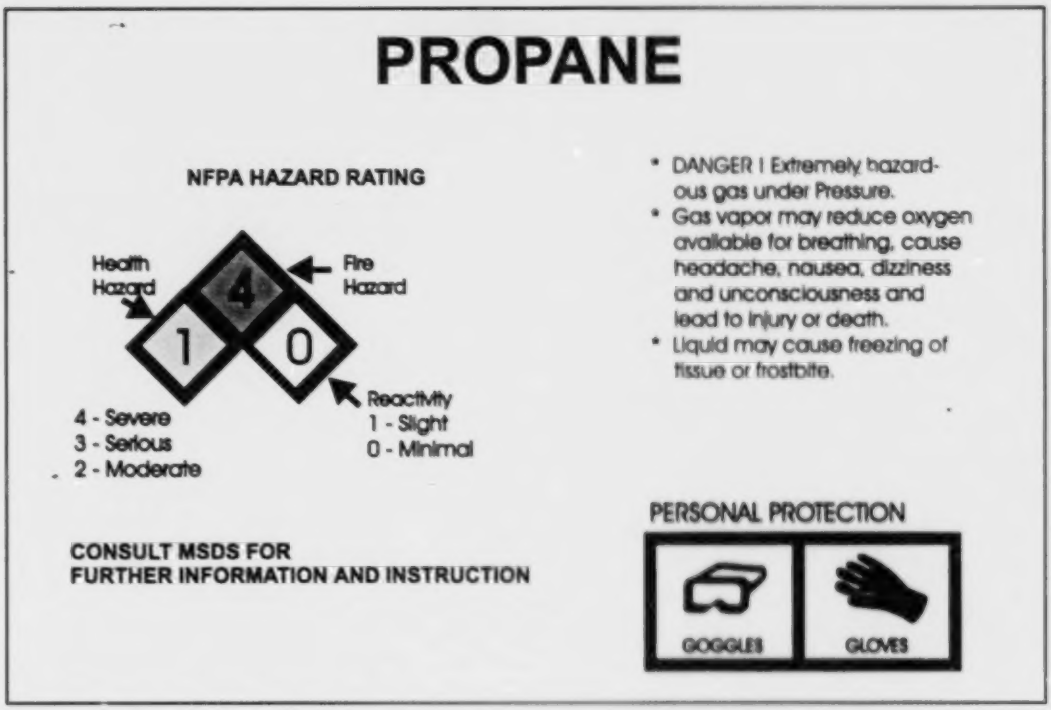

Figure 4.4 Propane Name Plate

Figure 4.5 National Fire Rating Label

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Name:	liquid petroleum gas, flammable gas, un1075
Form no:	sc-275, item #1000776
Description:	decal, red placard, black letters on white
Use:	required use on dot cylinders (Figure 4.5)

Repairs

Repair or alterations to any DOT or ASME container must comply with the regulations, rules, and codes under which the container was fabricated. Field welding of containers is strictly limited to attachments with non pressure parts such as saddle pads, wear plates, lugs, or brackets supplied by the container manufacturer.

Containers showing serious denting, bulging, gouging, or excessive corrosion must be removed from service. Steel containers that have been involved in a fire must also be removed from service. In a case where the tank shows no distortion, it may be sent back to the manufacturer and requalified or sent to a DOT approved repair facility. The container must be retested using the hydrostatic test procedures applicable at the time of original fabrication and all valves must be replaced. Aluminum cylinders must be permanently removed from service.

Valves

The following valves and apparatus are the same for both ASME and DOT applications (Figure 4.6):

1. Pressure relief valve
2. Fill valve
3. 80-percent liquid level gauge [fuel gauge (sending unit)]
4. manual shutoff liquid withdraw valve

In order to cut cost, many DOT tanks contain only those valves necessary to operate.

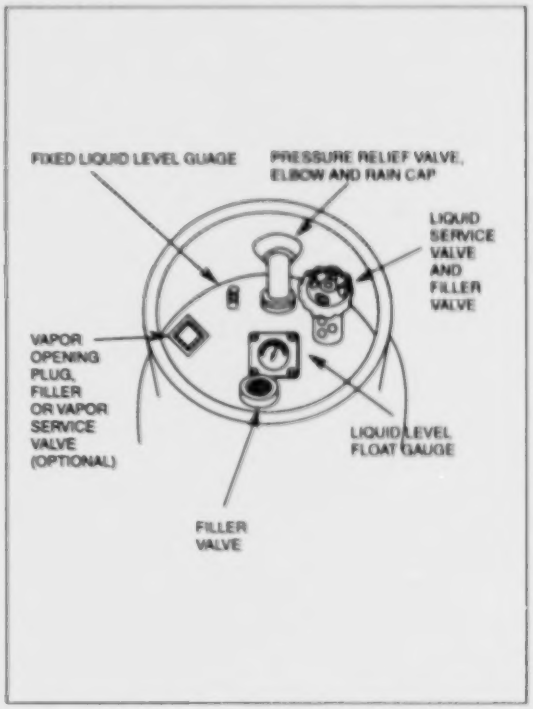
FIXED LIQUID LEVEL GUAGE
PRESSURE RELIEF VALVE, ELBOW AND RAIN CAP
LIQUID SERVICE VALVE AND FILLER VALVE
VAPOR OPENING PLUG, FILLER OR VAPOR SERVICE VALVE (OPTIONAL)
LIQUID LEVEL FLOAT GAUGE
FILLER VALVE

Figure 4.6 Arrangement of Valves and Fittings on Cylinder

PROPANE TANKS

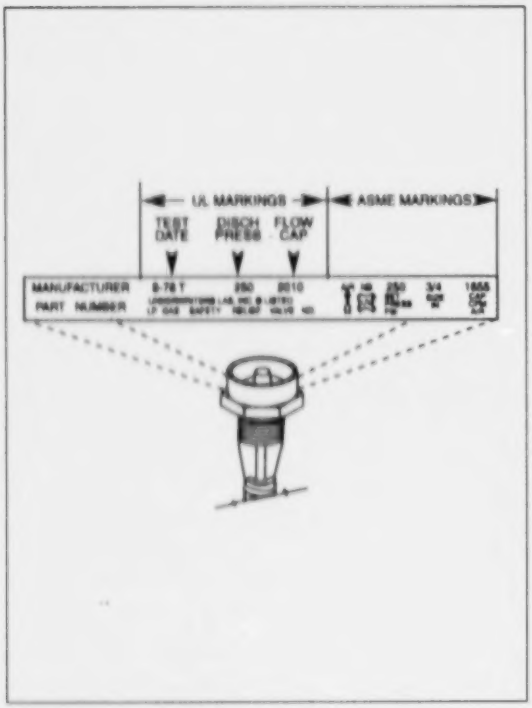

Figure 4.7 Relief Valve

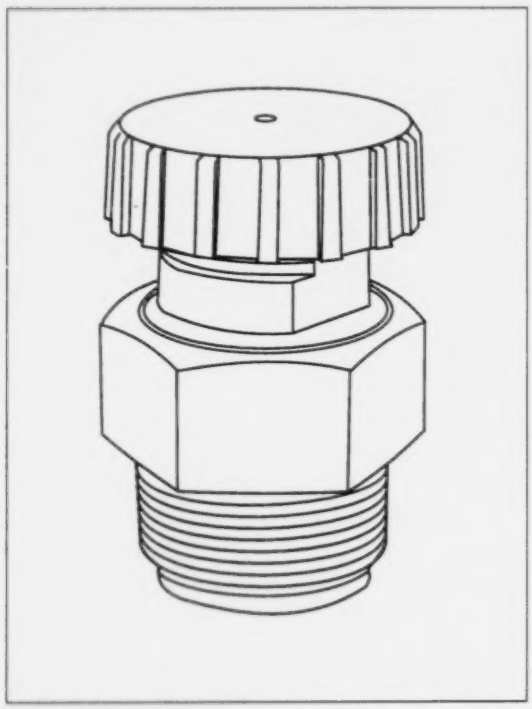

Figure 4.8 Filler Valve

All valves on a propane tank have an internal check valve or excess flow valve that is designed to prevent fuel from discharging from the tank if the valve is sheared off in an accident.

Pressure Relief Valve

This valve provides overpressure protection to the cylinder. It should be kept clean and unrestricted and positioned in the 12 o'clock position when the tank is mounted horizontally, whether on the forklift or in storage racks. A deflector is screwed into the relief valve which directs the fuel away from the driver upward at a 45 degree angle. The valve should have a dust cap to prevent dirt and debris from clogging it. The valve carries a number of markings such as test date, discharge pressure, flow capacity, and a UL approval seal.

The pressure relief valve will open to relieve any pressure that exceeds the rating stamped on the valve (375 psi for forklifts) (Figure 4.7).

Fill Valve

This is the valve through which the tanks are refueled. This valve has an internal, double backflow check valve necessary to prevent fuel loss in the event of an accident. If the top portion of the fill valve is sheared off, the fuel will remain locked inside the tank. This valve should be covered with a plastic cap. ASME tanks manufactured after January 1, 1984, for use as motor fuel containers must be fitted with an automatic means to prevent the tank from overfilling. When remote filling is used, a double backflow check valve must be installed in the container's fill valve opening (Figure 4.8).

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80-Percent Liquid Level Valve

This gauge is also called a "sight gauge" or "bleeder valve." When opened, this valve will allow vapor to escape from the tank through an orifice (#54 drill size) that connects to a tube within the tank. During filling operations, the valve is opened. When the liquid level of propane inside the tank reaches its 80 percent capacity, liquid propane then exhausts, forming a solid white stream of discharge. Propane tanks must not be filled beyond this level in order to allow sufficient room for thermal expansion (Figure 4.9).

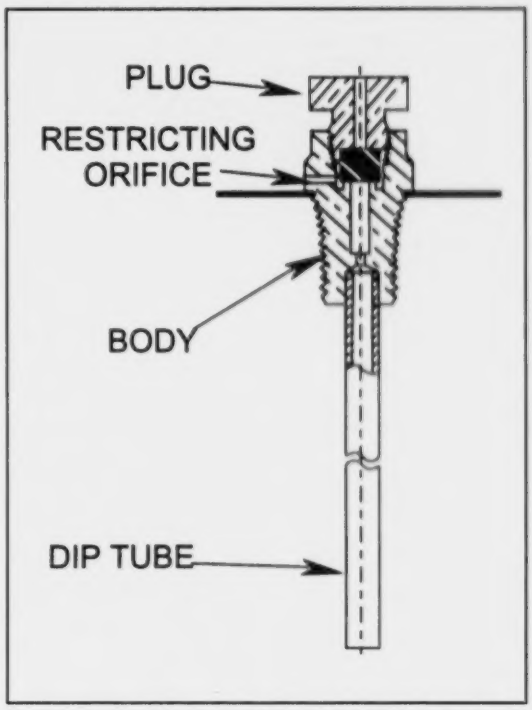

Figure 4.9 Fixed Liquid Level Gauge

Fuel Gauge

Some DOT tanks do not have fuel gauges. ASME and DOT tanks that do have fuel gauges use a magnetic liquid level float gauge inside of the tank. A site gauge or a sending unit may be placed on the external portion of the gauge to indicate the amount of fuel in the tank. If a sending unit is used, the OHM resistance matches the receiving unit to be read at the operating area of the vehicle (Figure 4.10).

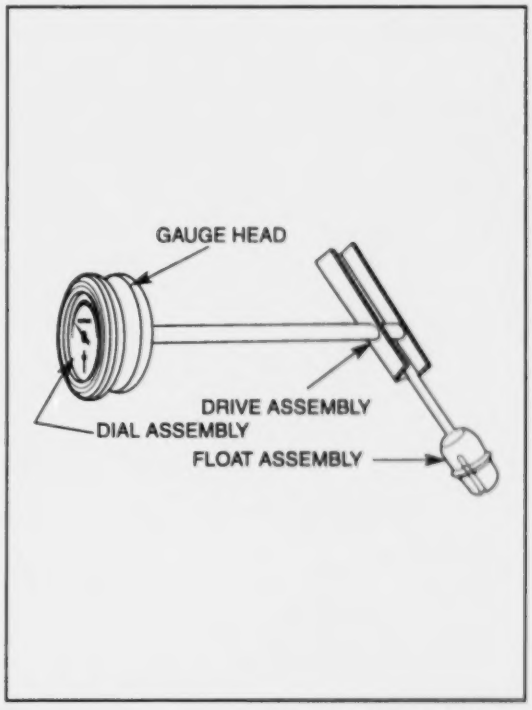

Figure 4.10 Float Gauge

Manual Shutoff Liquid Withdraw Valve

This valve is designed to provide positive closure. It can be shut off manually for service or for emergencies. It is equipped with an internal excess flow check valve designed to close automatically at the rated flow of vapor or liquid specified by the manufacturers. The line carrying the fuel to the propane fuel system flows through this valve. If for any reason the line would become severed, the flow of fuel would increase to the point that the excess valve would slam closed, locking the fuel inside of the tank. It is mandatory that when the propane tank is in use, the valve is completely open. If the valve is only partly open, the vehicle may not be getting enough fuel

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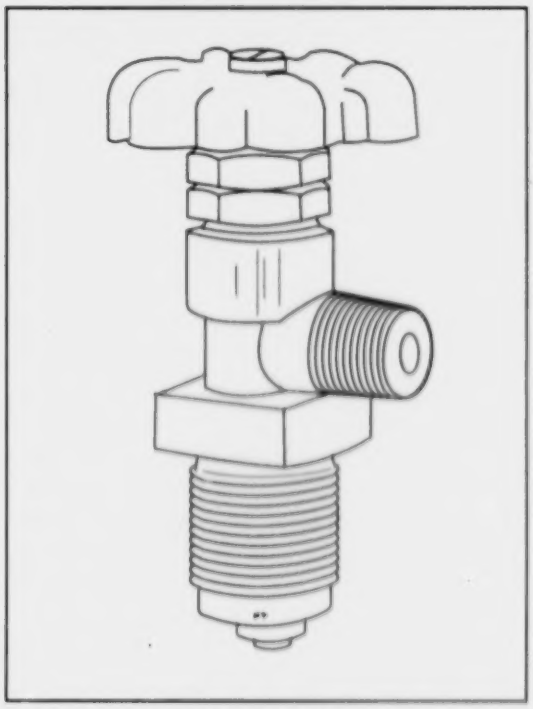

Figure 4.11 Liquid Service Valve

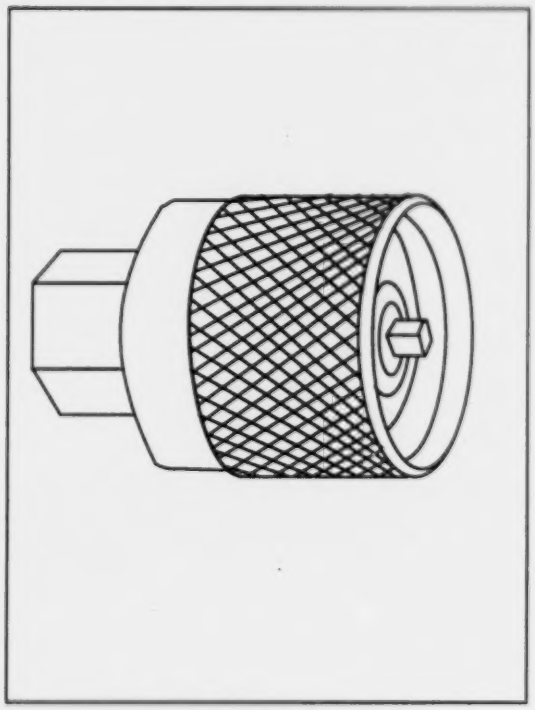

Figure 4.12 Female 1/4" ACME Motor Fuel Safety Check Connector

to operate efficiently. In this case, however, if the line is ruptured, the valve is controlling the flow of fuel. The excess flow check valve will not feel the impact of the broken line and not slam shut (Figure 4.11).

Quick Disconnect Couplings

The liquid withdraw valve on a DOT tank has male threads and accepts the male portion of a quick coupling. The female portion is adapted to the liquid hose going to the carburetion system. Both halves are equipped with 100 percent shutoff valves and, as they are coupled together, they open and allow gas to pass (Figure 4.12).

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The male portion of the coupling acts as an added safety check valve. If the liquid withdraw valve is turned on while the tank is in transit or if a passerby turns the wheel of the valve, no gas can escape. This coupler has two seals. One is an "o" ring and the other is a flat washer. The "o" ring prevents leakage from the shaft on the other coupling and the flat washer bottoms out and seals when the coupler is fully connected. Both the washer and the "o" ring must be replaced before they cause a leakage of fuel. The flat seal will sometimes pop off when disconnecting and slide up the shaft of the other portion of the connector, causing the valve not to open when fully mated. The extra washer must be removed from the shaft and recon-nected. Usually the propane company that is servicing the account will leave extra washers at the customer's location (Figure 4.13).

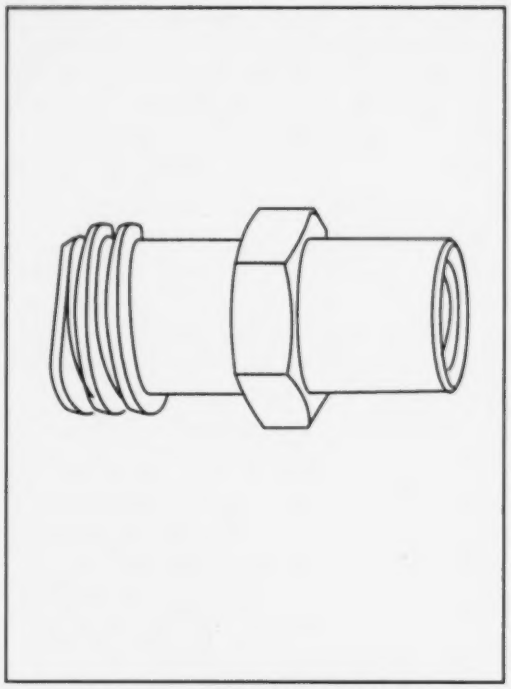


Figure 4.13 Male 1/4" ACME Motor Fuel Safety Check Connector

Cylinders

The CNG cylinders used on forklifts are manufactured to the following standards: DOT and NGV-2. Cylinders can be manufactured using steel, composite (fiberglass) wrapped steel or aluminum, or total composites. Steel cylinders must be hydrostatically tested every 5 years. Composite wrapped steel or aluminum cylinders, if built to the DOT standards, can be pressurized to 3,000 psig. This cylinder must be hydrostatically tested every 3 years. Composite wrapped steel or aluminum cylinders can also be manufactured to the 3,600 psig. NGV-2 standards. The third type of cylinder, total composites, can be pressurized to 3,600 psig and are built to the NGV-2 standards. NGV-II rated cylinders must be visually inspected yearly. They can be left in place for the 15 years, unless a problem is detected during yearly inspections.

CNG cylinders are not easily removed. Therefore, they are filled while on the forklift. There are two methods of filling these cylinders. The first is timed-fill, which means that the cylinder is filled while connected directly to the compressor. The average cylinder size is 5 to 7 (propane-equivalent) gallons. The other method of filling a CNG cylinder is fast-fill. The compressor fills a cascade of storage bottles or ASME tubes. When this system is hooked-up to the forklift's CNG cylinder, it can fast-fill at the rate of two to five minutes per fill.

CNG Tank Labeling

Steel CNG cylinders have the manufacturing code, test date, and rated pressure stamped on the neck of the tanks. Composite cylinders have a label with the appropriate information that is below the surface of the final epoxy coating. The cylinder must be positioned so that the label can be viewed while in place on the machine.

CNG Cylinder Service Valves

The CNG cylinder service valve may look similar to a propane tank valve on the out side; but they are different. First, it is equipped with temperature and pressure relief devices (PRD). The device does not reset automatically. When opened, all system pressure will be vented to the atmosphere. The cylinder type and manufacturer determine the relief device used. These devices are marked with a pressure and temperature rating. Always replace this device with one of the exact style, pressure, and temperature rating.

CNG Tank Inspection

CNG tank inspection procedures have always been important. Inspection of tanks while in use is the responsibility of the operators and technicians. Both should check the condition of cylinders by using the following guidelines:

Ensure the cylinder installation guidelines are followed as provided for in the National Fire Protection Association (NFPA) 52 standard. Protect cylinders from damage due to physical contact with debris and other objects with composite wrap materials. Use open, self-draining shielding systems to protect cylinders from physical damage, if necessary.

Make sure that approved vehicle or cylinder manufacturer cylinder brackets and gaskets have been used. This will reduce or prevent abrasions and other damage to the cylinder over-wrap and to prevent other fluids from seeping under the gaskets and possibly causing unseen damage.

When filling a cylinder, do not, under any circumstances, pressurize the CNG cylinders above the pressure rating of the cylinder.

Cylinder over-pressurization lowers the margin of safety, decreases cylinder life, and can lead to the rupture of a damaged cylinder.

Operators should conduct periodic general cylinder inspections to look for signs of cylinder damage, when they refuel. Technicians should inspect cylinders for signs of damage when performing routine vehicle maintenance.

If the operator of a vehicle or a technician identifies a damaged NGV compressed gas cylinder, take immediate action to determine whether the cylinder is fit for continued service. Overlooking such conditions represents a serious safety risk. Damaged cylinders should be inspected immediately by qualified personnel.

Improved practices and increased awareness of potential risks can help ensure that NGVs provide reliable and safe service. To achieve this goal, NGV owners and operators are urged to formalize training and awareness and to employ best practices in the installation, filling, operation, and maintenance of compressed gas cylinders.

Mounting Brackets

Mount brackets securely to the vehicle. Use either a strong portion of the vehicle or large backing plates or washers to prevent bracket/cylinder movement. This is especially important when mounting on sheet metal.

Always use cylinder manufacturer approved brackets, gaskets, bolts, washer, etc. Substitutes should be avoided. Using brackets designed for another cylinder should not be done. It is critically important that the proper rubber gaskets be installed between the cylinder and bracket.

Maintenance

When performing general maintenance on a machine, it is beneficial to spend some time doing a visual inspection of the CNG cylinders. Jacks and hoists should be prevented from contacting the cylinders.

High pressure gas is powerful and dangerous as well as flammable. Welding equipment or torches should not be used near cylinders or high pressure gas lines. Tools and hammers should not be used to hit or strike the cylinders or fuel lines. Do not pull on the fuel lines or valves on cylinders if doing cylinder maintenance, use extreme caution.

Contact the cylinder manufacturer for guidelines on safe venting. Use caution when repressurizing or venting high-pressure gas. Always use grounding-cables to prevent static electricity from building up a spark. Cylinders require extreme caution when venting. Rapid gas venting can chill plastic tanks and make them brittle and prone to breaking or cracking. This raises the risk of damaging a cylinder and causing leaks.

If removing a cylinder from a vehicle, make sure the cylinder is properly supported. Cylinders are heavy and awkward for one or even two people to properly balance and carry.

In addition to possible cylinder damage from mishandling, having people hold and carry cylinders can result in injuries (e.g., back strains). Use all means possible to ensure that cylinders are not dropped, dragged or rolled on the ground. This is especially important for composite wrapped cylinders. A transmission cradle or similar device may be useful for supporting and transporting a cylinder.

Summary of Guidance

Exemption Cylinders (DOT-RSPA)

The DOT recommends that users of CNG cylinders first consult the cylinder manufacturer for guidance on inspection and re-certification requirements. The DOT specifically indicates that the use of hydrostatic testing is not encouraged. Users of CNG cylinders are encouraged to use inspections by qualified inspectors, and conduct routine inspections by machine operators, mechanics, or other in-house personnel. More frequent inspection is an added safety procedure.

ANSI/NGV2-1992 Cylinders

ANSI stipulates a Detailed Visual Inspection every three years by qualified inspectors using cylinder manufacturer criteria and following Compressed Gas Association (CGA) guidelines. Testing procedures are also recommended, however, hydrostatic testing is not required or recommended as an inspection technique by ANSI. Users are encouraged to implement periodic routine inspections by machine operators, mechanics, or other in-house personnel, along with Detailed Visual Inspection.

NGV Cylinder Inspection Options

Hydrostatic Testing

Hydrostatic (or "hydro") testing of compressed gas cylinders is common practice for recertification of compressed gas (e.g., air and nitrogen) cylinders. The effectiveness and appropriateness of this practice for CNG cylinders are open to some question. The DOT and ANSI provide specific recommendations against the use of hydrostatic testing.

Non-Destructive/Acoustic Emissions Testing

Acoustic Emissions (AE) testing is a non-destructive testing (NDT) technique used in various industries for evaluating the fitness of structures-including tubes and cylinders. Neither existing DOT-RSPA cylinders nor existing NGV2-1992 cylinders have regulations which identify AE or other NDT methods as an approved inspection technique. Therefore, the use of AE in place of detailed visual inspection should only be done with approval of the cylinder manufacturer.

Propane Hose and Fittings

High pressure, flexible, hose and matching fittings are commonly used. The hose and connectors used for conveying liquid or vapor at pressures are fabricated of materials resistant to the action of propane, both liquid and vapor. They incorporate a wire braid-reinforced construction. The hose is designed for a working pressure of 350 psig with a burst pressure of 1750 psig. It is marked on the outside of the hose with: LP-gas, Propane, 350 psig working pressure, and the manufacturer's name or trademark. Each installed piece of hose must contain at least one such marking (Figure 6.1).

Hose and fittings that are used to carry liquid propane forward toward the fuel lock must be approved for propane use (Figure 6.2). Although cast iron fittings must not be used, fittings made of steel, brass, copper, malleable iron or ductile iron may be used. Although these materials are approved for propane, they are rarely, if ever, found in the field.

Never use hydraulic hose. Although the hoses look the same, the inner rubber wrap of the hydraulic hose is more porous and the propane can weep through. Although not enough will leak to ignite, the odor of propane is present. If a leak should develop, the hose will swell or blister, trapping propane between the inner and outer layers of the hose. Therefore, the proper hose should always be used (Figure 6.3).

CNG Lines and Fittings:

The high pressure fuel line used from the cylinder to the high pressure regulator is normally 1/4" stainless steel tubing. The most common connectors are double ferule stainless connections. Ferule profiles change from manufacturer to manufacturer. Do not interchange these connections, as a

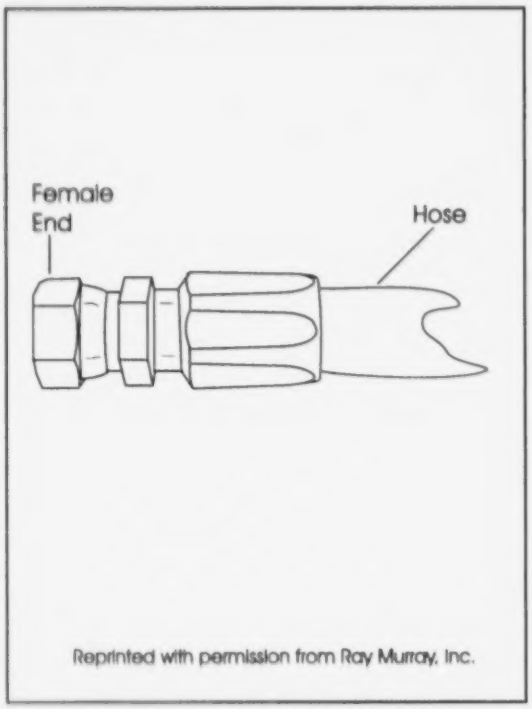


Figure 6.1 Swivel Female Flare Fitting for Stainless Braid Motor Fuel Hose

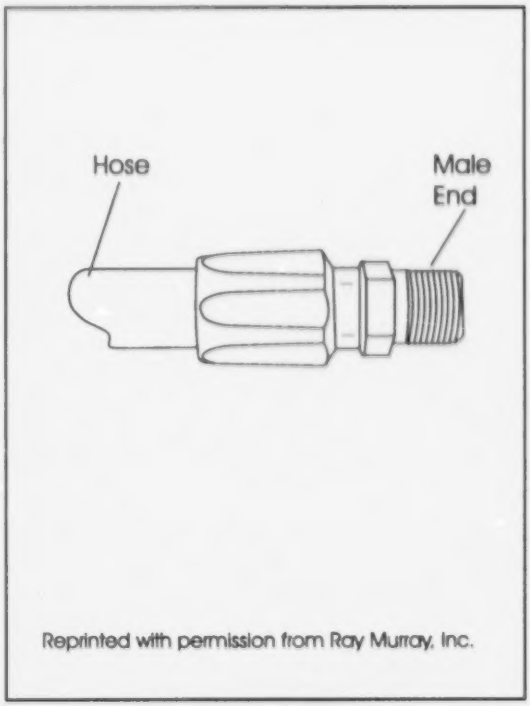


Figure 6.2 Male Flare Fitting for Stainless Braid Motor Fuel Hose

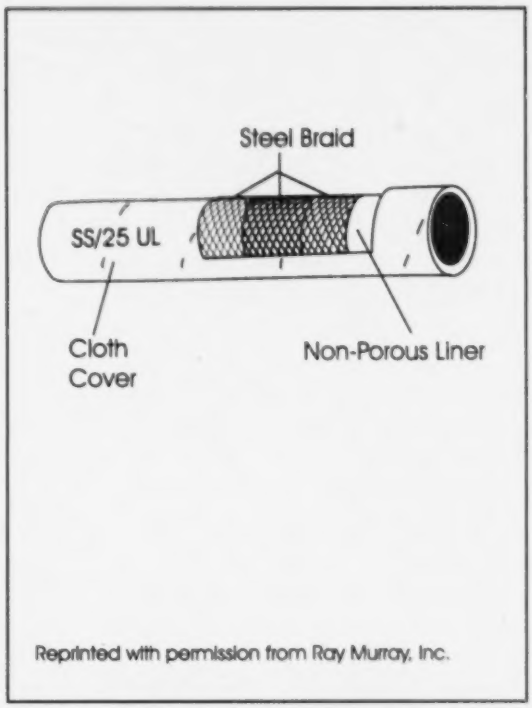


Figure 6.3 LPG Stainless Steel Braid Hose with Cloth Cover for Motor Fuel

line may blow out or not seal its connection when pressurized. Standards for fuel line, connectors and installation procedures are laid out in NFPA 52.

From the High Pressure Regulator forward, the lines, connectors, etc., are the same as those used in a propane installation. The same practices apply to this line as it does for a propane system.

Automatic Shutoff Valve

An approved automatic shutoff valve, more commonly known as a lockoff or fuel lock, must be provided in the fuel system and installed as close as practical to the gas regulator. This valve prevents fuel flowing to the regulator and mixer when the engine is not running, even if the ignition switch is in the ON position. Zero governor regulators cannot be considered as an automatic shutoff. There is an exception. Demand type regulators (zero governors) used for portable engines of 12 horsepower or less, with magneto ignition and used exclusively outdoors, can be considered to be in compliance with the regulations—normally having no ignition switch. These are shut off by closing the tank valve and allowing the engine to run out of fuel.

The reason a lockoff is required is to prevent fuel flow past the primary seat in the regulator, if this seat were to fail. Gas in that portion of the regulator would equal the gas pressure in the tank. It (the gas) would then force open the secondary valve and travel through the regulator and out through the carburetor and air filter into the atmosphere. As it mixes with air, a potential hazardous situation is created.

Types of Fuel Lockoffs

There are two types of fuel locks that are used in a gaseous fuel system: 1) electrically activated fuel lock, and 2) vacuum activated fuel lock. The electrical lockoff is nothing more than a magnetic coil which, when energized, lifts the piston off its seat, allowing gas to flow. When the current stops, a small spring forces the piston back down, covering the seat and stopping the flow of fuel (Figure 6.4). In order to meet the code which states that the fuel lock must close when the engine is not running, a safety switch must be added. There are various types of safety switches used: a vacuum safety switch, an oil pressure safety switch, and an electronic device that senses secondary ignition pulse. These switches stop the flow of current to the lockoff when the engine is not running, even if the key is on.

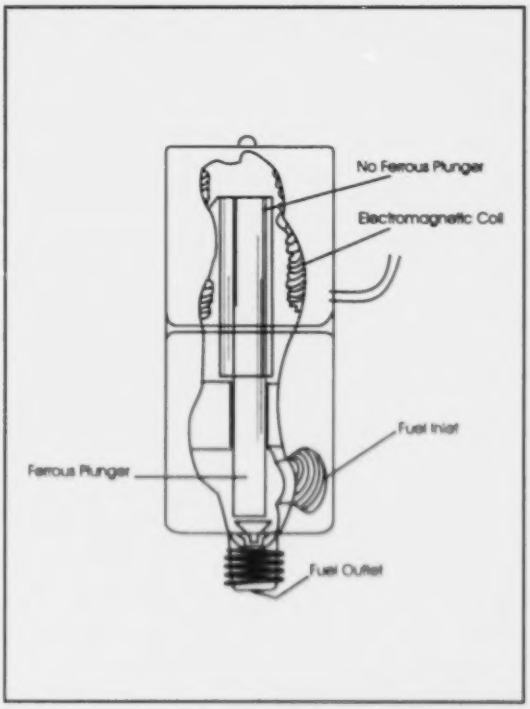


Figure 6.4 Electric Lockoff

Some fuel lockoffs incorporate a filter to remove impurities as part of the lockoff. Most forklift applications use a small electric lockoff and a separate filter which is incorporated as part of the fuel system. The internal portion of the filter may look like a gasoline filter because the fuel is in a liquid state similar to gasoline. Some filters also contain a magnet. Steel fuel cylinders may contain rust flakes and metal scale. If these particles go through the system, they could get under the regulator valve seats (Figure 6.5).

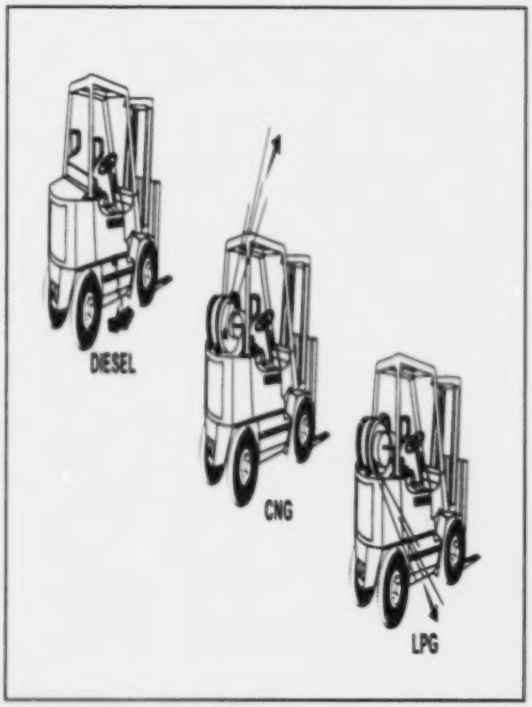


Figure 6.5 Vacuum Fuellock Filter

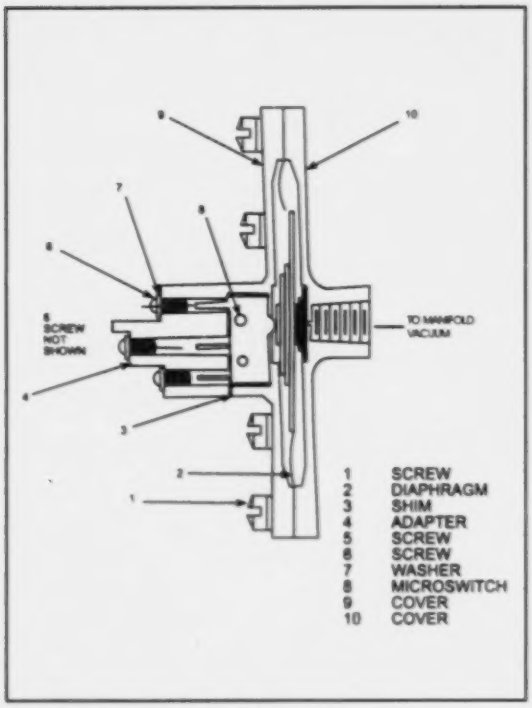


Figure 6.6 Vacuum Switch

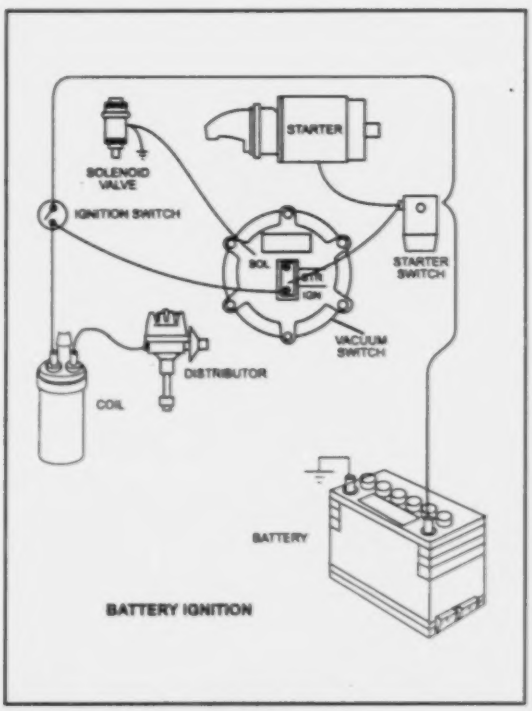


Figure 6.7 Vacuum Safety Switch

Vacuum and Oil Pressure Switches

The vacuum safety switch can be a two- or three-pole switch. A vacuum switch is a canister with two contact posts: an internal diaphragm and contacts, and a vacuum port (Figure 6.6). When a vacuum is applied to the canister, electrical currents pass when the diaphragm is pulled against the contacts. When the engine is not running, contact is broken because there is no vacuum present.

In three-pole vacuum switches, the third pole used is for a starter by-pass so electrical current can energize the lockoff during engine cranking (Figure 6.7).

The oil pressure safety switch operates similarly to the three-pole vacuum switch, except it is activated by engine oil pressure. It takes 4 pounds of oil pressure to close the terminals. The oil pressure switch has one advantage over the vacuum switch—this unit shuts off the fuel when the oil pressure drops below 4 pounds. This, in turn, stops the engine, possibly preventing serious engine damage (Figure 6.8).

Vacuum Fuel Lock

Since this lockoff requires engine vacuum for activation, it meets all safety requirements. This lockoff consists of very few parts. Gas flows in the filter side and stops until vacuum is applied. A hose from a special port in the carburetor supplies a constant 6" WC vacuum. This vacuum activates a diaphragm, drawing it down. This action, in turn, pushes an arm which lifts the valve off its seat. When the valve is lifted, gas is allowed to pass through the lockoff. The pin that is used to lift the seat goes from the vacuum chamber into the propane chamber. There is an "o" ring that the pin goes through. The pin or small shaft is Teflon coated (Figure 6.9).

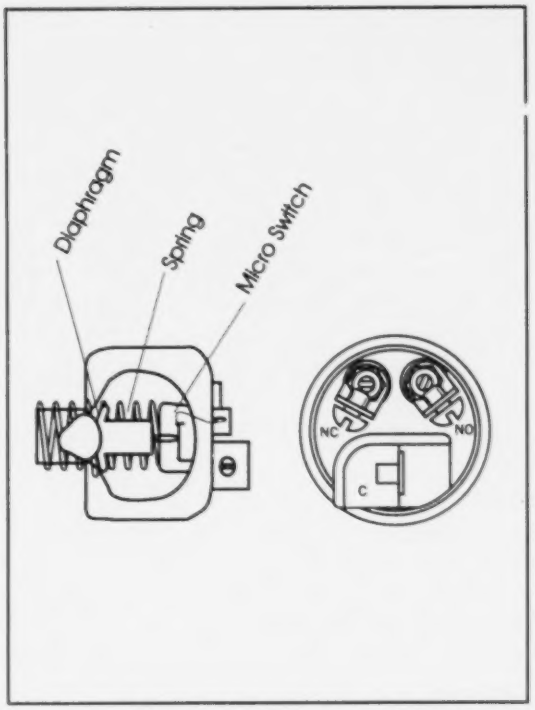
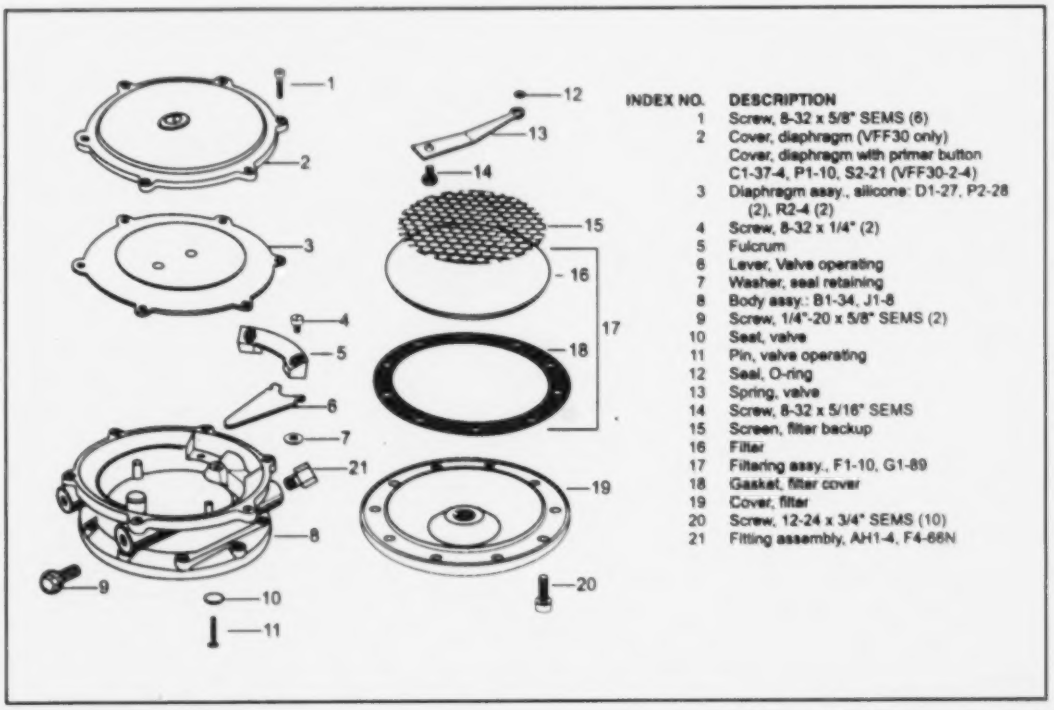


Figure 6.8 Oil Pressure Safety Switch



INDEX NO.	DESCRIPTION
1	Screw, 8-32 x 5/8" SEMS (6)
2	Cover, diaphragm (VFF30 only)
	Cover, diaphragm with primer button C1-37-4, P1-10, S2-21 (VFF30-2-4)
3	Diaphragm assy., silicone: D1-27, P2-28 (2), R2-4 (2)
4	Screw, 8-32 x 1/4" (2)
5	Fulcrum
6	Lever, Valve operating
7	Washer, seal retaining
8	Body assy.: B1-34, J1-8
9	Screw, 1/4"-20 x 5/8" SEMS (2)
10	Seat, valve
11	Pin, valve operating
12	Seal, O-ring
13	Spring, valve
14	Screw, 8-32 x 5/16" SEMS
15	Screen, filter backup
16	Filter
17	Filtering assy., F1-10, G1-89
18	Gasket, filter cover
19	Cover, filter
20	Screw, 12-24 x 3/4" SEMS (10)
21	Fitting assembly, AH1-4, F4-66N

Figure 6.9 Vacuum Fuellock

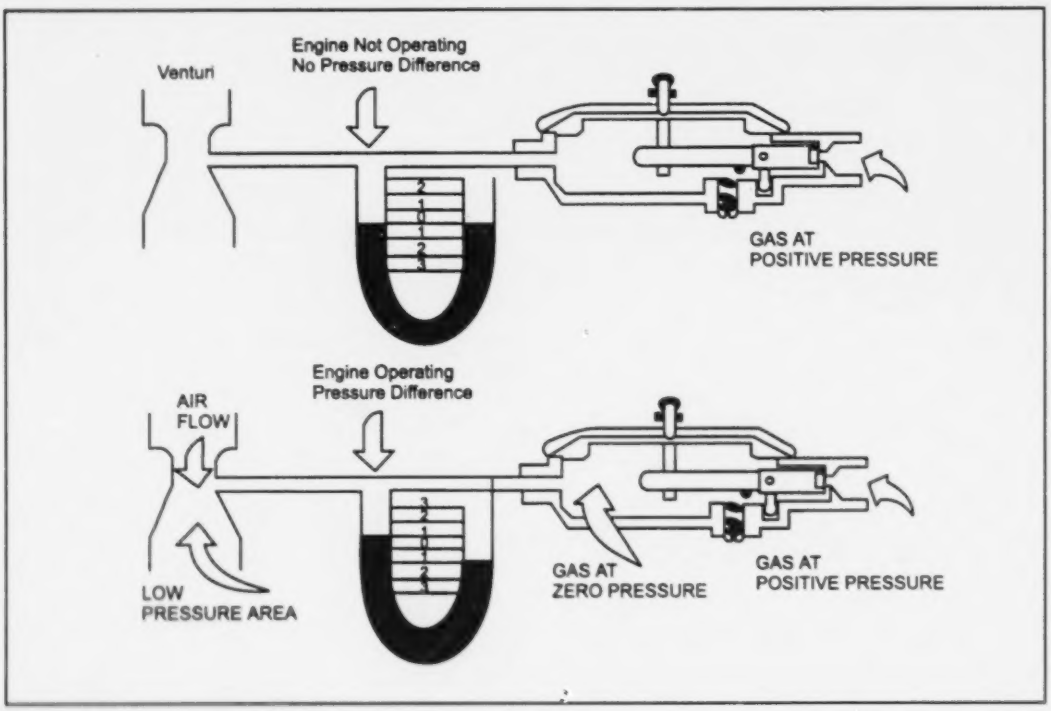
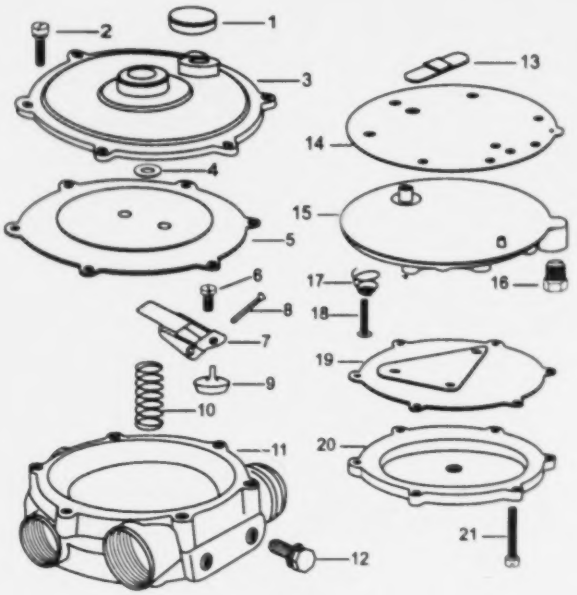


Figure 6.10 Pressure Differences

Vaporizer Regulators and Gas Mixers:

Atmospheric pressure

Atmospheric pressure is the pressure exerted on the air (atmosphere) around us. If we had 1 cubic foot of air at sea level the absolute pressure on this cubic foot of air would be approximately 14.7 lbs./sq.in. this is known as barometric pressure. If a pressure reading was taken on the same cubic foot of air in the mountains of Colorado at 7,000 ft. above sea level it would be approximately 12.3 lbs./sq.in. and in outer space the reading would be 0 lbs./sq.in. this is what is known as absolute zero pressure. When a pressure measurement is taken in PSIA this means it is in pounds per square inch above absolute Zero. If a pressure measurement is taken in PSIG this means it is taken in pounds per square inch gauge or a pressure above atmospheric pressure. A pressure above atmospheric pressure is



INDEX NO.	DESCRIPTION
1	Screen, atmospheric vent (Model J only)
2	Screw, 8-32 x 5/8" SEMS (6)
3	Cover assy., secondary: C1-34, P1-10, S2-21, W1-27, S7-4
4	Washer, hand primer
5	Diaphrgm assy., secondary: hydrin; D1-26, P2-28, P2-27, R2-4 (2)
	Diaphragm assy., secondary, silicone: D1-27, P2-28, P2-27, R2-4 (2)
6	Screw, 8-32 x 3/8" SEMS
7	Lever, secondary regulator
8	Pin, secondary fulcrum
9	Seat, secondary regulator (new)
10	Spring, blue secondary, standard
	Spring, orange secondary, optional
11	Body assy.: B1-33, J1-7, P3-14, J1-15
12	Screw, 1/4" - 20 x 5/8" SEMS (2)
13	Seat, primary regulator
14	Gasket, body to plate
15	Plate, converter body cover
16	Plug, 1/8" pipe; hex head
17	Spring, primary regulator
18	Pin, primary valve
19	Diaphragm assy., primary: D1-22, P2-29, R2-3, (3), L1-36
20	Cover, primary regulator
21	Screw, 8-32 x 1" SEMS (7)

Figure 6.11 Converter Breakdown

known as a positive pressure a pressure below atmospheric pressure is known as a negative pressure (Figure 6.10).

Vaporizer regulator (Converter)

Depending on the fuel system design, this device can play multiple roles in the system operation. They are:

1. It reduces the fuel from tank pressure to a pressure governed by the particular regulator design, usually from 1.5 psi - to 5 psi.
2. It helps complete vaporization. Propane enters the expansion chamber of the vaporizer as a liquid, immediately starting to vaporize, absorbing heat provided by the engine's cooling system. By the time it reaches the other end of the chamber, it is fully vaporized and ready to enter the secondary side of the regulator (Figure 6.11).

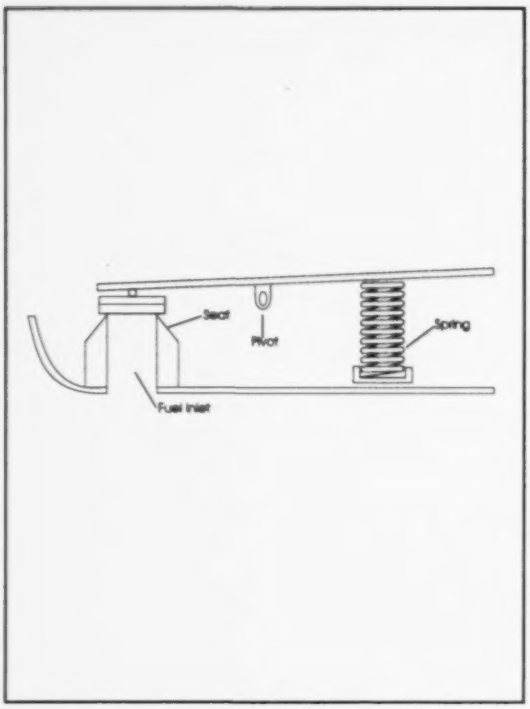


Figure 6.12 Float and Needle Valve

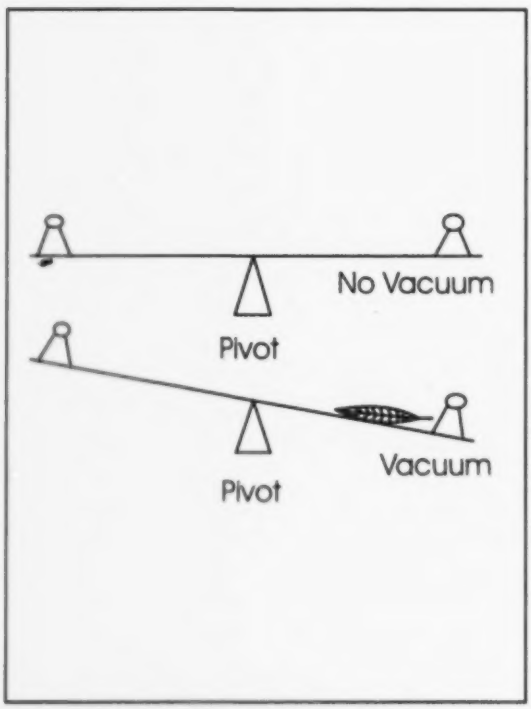


Figure 6.13 Principle of Differential Pressure

3. The most common type of secondary regulator is known a demand type. NOTE: Some manufacturers have two separate units for the primary and secondary regulators, but normally they are one unit.This portion of the regulator performs the same function as the gasoline carburetor float system—both regulate fuel flow from the fuel inlet into the fuel delivery portion of the system. In a gasoline system, the float and needle valve maintain the liquid fuel level (pressure) needed to meet the fuel demands of the engine. When using gaseous fuels, this job must be done with a vacuum sensitive diaphragm and valve, holding a pressure level of zero or at slightly below atmospheric pressure (up to 1.5" WC).

While a demand regulator has the same basic elements as a common pressure regulator, [namely, a diaphragm (sensing element), a spring (loading element), and seat-orifice (restricting element)], they differ in their relationship to each other. In the common pressure regulator, when pressure is applied to the inlet, fuel flows through the outlet—if it is not plugged or restricted. This is not the case with a demand regulators. Fuel will not flow unless a vacuum is applied to the diaphragm chamber. In a demand regulator, a round orifice and a flat rubber seat to control fuel flow are attached to one end of a lever. A pivot pin with spring force is attached to the other end of the lever (Figure 6.12).

A demand regulator can be visualized as a teeter totter or seesaw with a fifty pound child on each end of the lever. Equal forces balance the lever. The system is balanced by the fuel pressure trying to force the valve open and the spring tension acting to keep the valve closed. A small amount of force applied to one end of the lever will upset the balance and cause movement (Figure 6.13).

This force occurs when the venturi suction applied to the diaphragm causes the higher atmospheric pressure on the opposite side to move the diaphragm toward the lever. When the diaphragm applies force on the spring end of the lever, the balance is upset, the valve opens, and gas is allowed to flow.

If gas pressure is greater than the spring force applied to the inlet seat, the excess pressure forces past the orifice and causes a leak. However, if too much gas pressure flows into the body case, the diaphragm lifts and assists the spring in closing the valve.

The Gas Mixer/Carburetor

As with their gasoline counterparts, there are several different principles of operation employed in gas mixers. For example, most American technicians are very familiar with the fixed venturi carburetor such as a Holly or Carter. Those who repair European cars or motorcycles are also familiar with the variable venturi carburetor such as the SU or CD Strongberg. Because most people are more familiar with the fixed venturi gasoline carburetor, we will first describe the gaseous fuel version before tackling the more popular variable venturi system that is used in most industrial applications (Figure 6.14)

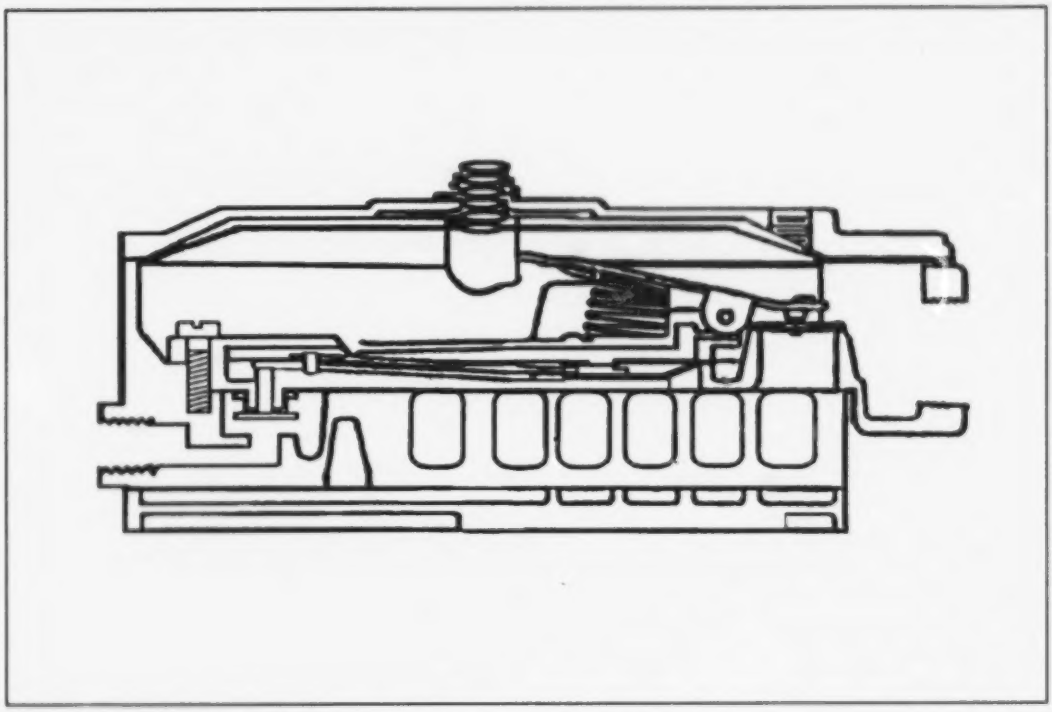


Figure 6.14 Gas Mixer Carbureter

Purpose of the Gas Mixer/Carburetor

Because the fuel is supplied to the mixer/ carburetor as a gas and not a liquid, it is normally a simpler device than that used for gasoline systems. Thus, the purpose of the gas carburetor or mixer is to:

1. Input gas vapor into the engine,
2. Measure the mass of intake air, and
3. Measure the correct amount of gas and MIX it with the intake air so as to create a homogeneous mixture.

General Requirements

If bi-fuel, it should have a minimal influence on the gasoline operation of the vehicle. It should operate on gas in an optimal way with regard to performance, fuel consumption and exhaust emissions. It should easily adapt itself to the existing carburetor throttle body or intake manifold.

Mixer Classification

Mixers can be classified as being either simple or complex in design. Simple (fixed) mixers do not have moving parts in their design. Simple mixers are designed to be used with complex converters.

Complex Mixers

Mixers, that have moving parts designed to vary the fuel flow can be classified as complex (variable) mixers. Such mixers typically have the idle adjuster located at the mixer (e.g., Impco and Century). Complex mixers are designed to be used with simple, two-stage converters (Figure 6.15).

There are four basic mounting configurations used in gas conversions: above carburetor systems, below carburetor systems, modified carburetor design, and dedicated gas systems.

Simple Systems

This type of system can consist of: a spray ring venturi device which is (a) fitted between the air cleaner and the carburetor, or (b) fitted in the existing air cleaner, or (c) a combined spray ring mixer and air cleaner assembly. Each of these can be fitted in line with the air intake hose on remote air cleaner applications.

The simplest of these is the "spud" type, which is a pipe inserted into the air cleaner that ends at the venturi.

Another simple type consists of a fixed venturi gas ring which has either slots or multiple hole gas ports drilled into the gas ring. These ports or slots ensure uniform fuel distribution into the air stream.

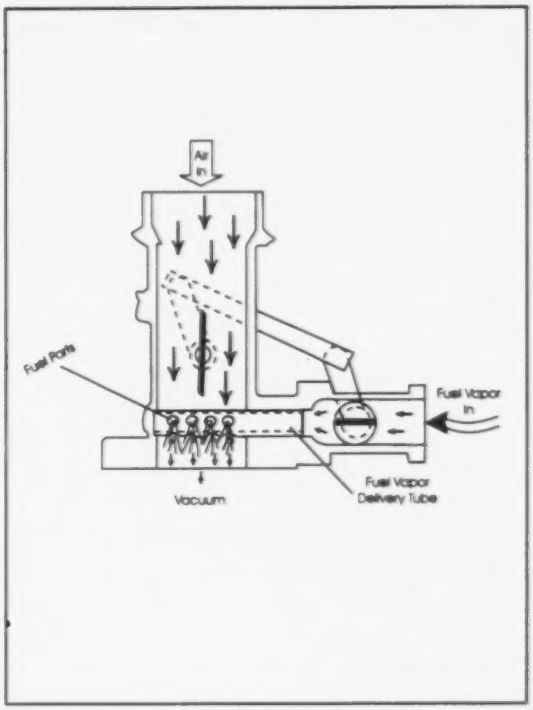


Figure 6.15 Complex Mixer

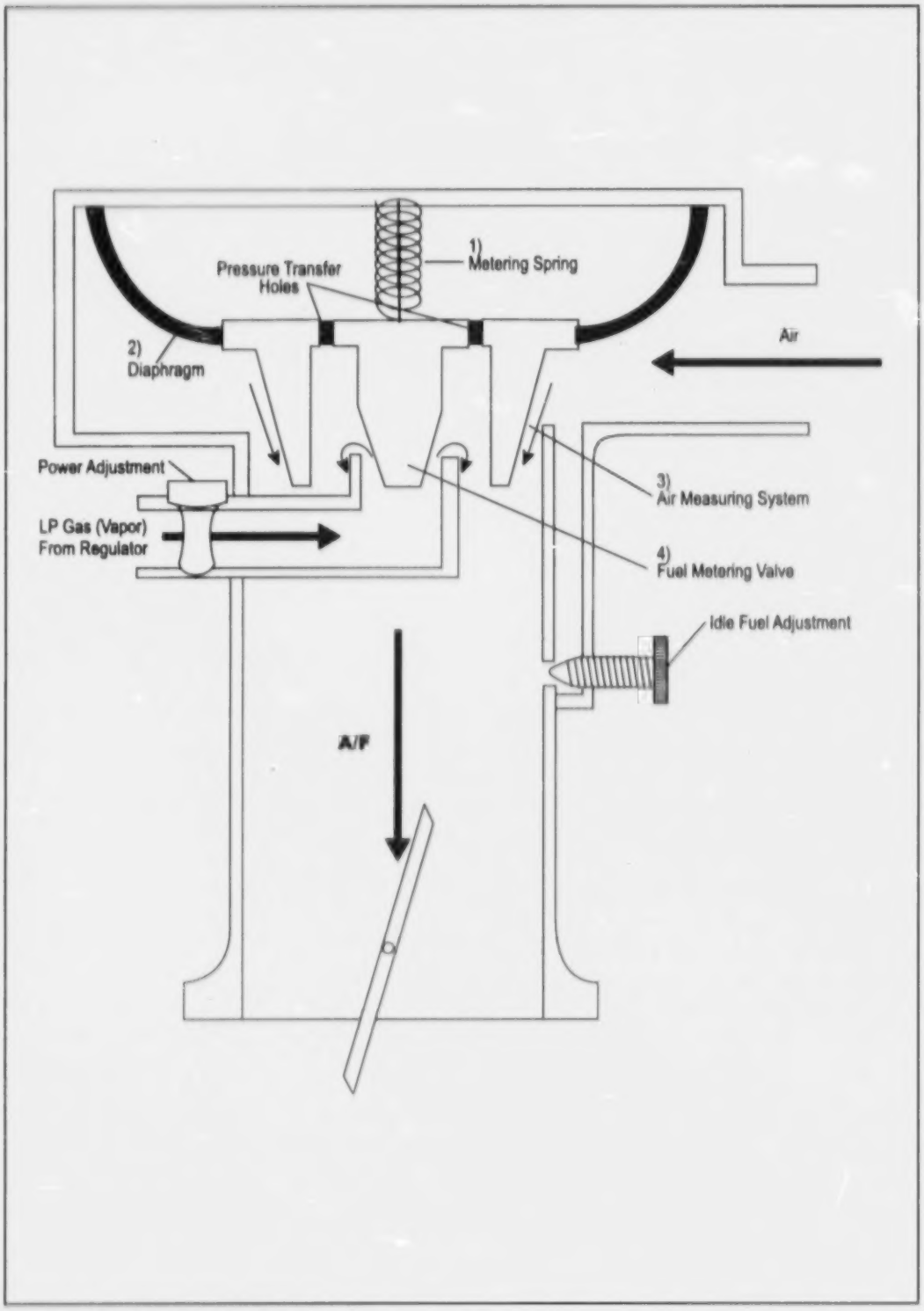


Figure 6.16 LP Gas Air Valve Carburetor

The Venturi Principle

As air is drawn into the engine by the piston, it must pass through a venturi which creates a low pressure (a vacuum) propor-tional to the amount of air being drawn through the venturi. Whereas the vacuum created by the venturi in a liquid fuel system acts on the discharge nozzle, main jet, and in turn the float and needle valve to draw in fuel, the low pressure generated in a gaseous fuel mixer acts upon a diaphragm in a fuel regulator (zero governor, final stage regulator). As the diaphragm is drawn toward the source of the low pressure, an attached lever opens a valve and allows the gaseous fuel to flow through to the carburetor. The proper fuel/ air mixture is then obtained by a mixture adjustment in the fuel line between the fuel regulator and the venturi (Figure 6.16).

This sounds very simple, and it is. However, the key to satisfactory performance in the venturi system is the sensitivity of the fuel regulator throughout its operating range. A properly set fuel regulator (zero governor, final stage regulator) using a rubber seat and spring tension against an orifice will shutoff the flow of fuel when the engine is not running. Yet, the slightest amount of vacuum should cause the seat to move and allow gas to flow. If the spring force is too great and requires a greater vacuum to open the device, a flat spot or sluggish progression off idle will develop with a possibility of lean mixtures and power losses at full load. Also, if the fuel regulator allows fuel to leak through at shutdown, a flood condition will occur similar to that in a liquid-fuel carburetor, resulting in hard starting and the danger of fire. In either case, the fuel controller should be readjusted per the specific instructions for the unit. The heart of a venturi type gaseous carburetion system is the regulators (Figure 6.17).

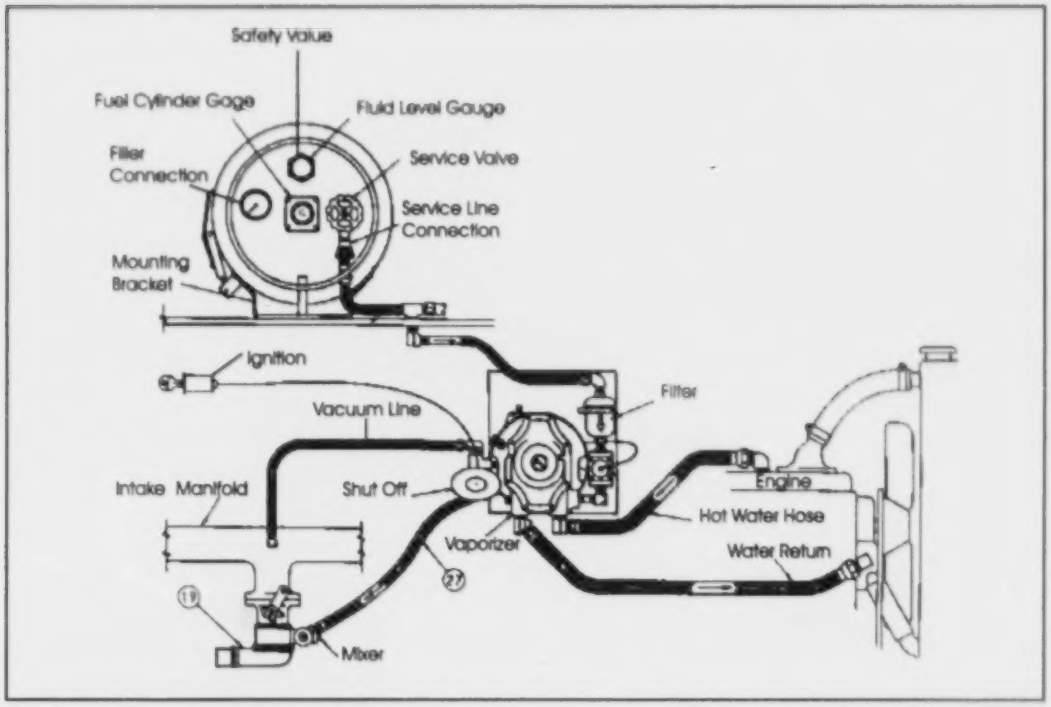


Figure 6.17 Gaseous Venturi System

Air Gas Valve Metering

The variable venturi concept has been around for many years. This system can work on both positive or negative regulator pressures. The air valve system operates on a constant pressure drop at the metering valve between idle and full load. A strong differential in pressure (neg. 1.5" w.c. or pos. 10"w.c.) yields excellent air/fuel mixture stability compared to the fixed venturi metering system.

As the engine cranks over, the downward movement of the pistons create a vacuum (low pressure) as it attempts to draw air into the cylinders (Refer back to Figure 6.16). A spring (1) is applying pressure on the diaphragm (2) holding it, the air valve (3), and the fuel metering valve (4), on their respective seats. The vacuum passes through the transfer holes into the area above the diaphragm. The vacuum acts on the

diaphragm causing it to lift. As it lifts, the air valve and fuel valve, which are mechanically attached to the diaphragm, also lift, thus drawing air past the air valve and fuel from the regulator past the metering valve. It takes approximately 6" WC vacuum to lift the valve off its seat.

As the demand for more power increases, the throttle fly opens further, creating a greater vacuum on the diaphragm which lifts further, allowing a greater amount of air and fuel to enter the engine.

Idle Adjustment:

There are several different methods used to control idle air/fuel mixtures. The most popular methods are described here. With the throttle fly nearly closed, the air and fuel metering valves are almost at rest in their seats. (This may not be the exact position necessary for all engines.) Air is allowed to bypass the air valve via an idle air passage. An adjustment screw (5) limits the amount of air that is able to bypass the air valve thus causing the air and fuel metering valves to rise or fall to the correct position for each engine application.

Part Throttle Mixers:

Part throttle mixtures are controlled by the fuel metering valve. The profile shape of this valve plays a very important role as to the exhaust emission levels the engine produces at part throttle. The valve is only partly out of the orifice and the power mixture adjustment has very little effect at this throttle position.

NOTE: Most manufacturers offer a variety of different valves, and care should be taken to assure the correct valve is replaced when repairs are being carried out.

Power Mixtures:

When the demand for full power is upon the engine, and the air/fuel valve is fully lifted, the fuel metering valve gives up its authority to control the fuel mixture and the authority is given to the power mixture control. The same mixer and engine may have a variety of applications so this necessitates that the full power mixtures be field adjustable.

NOTE: This should be set at maximum rpm with manifold vacuum 3" h.g. or lower.

The exhaust emissions from material handling equipment can increase through the lack of maintenance. This can cause the carbon monoxide inside a building to climb above the OSHA maximum limit of 50 ppm during an eight-hour period.

Carbon Monoxide Poisoning

Carbon monoxide (CO) is a colorless, tasteless, and odorless gas and gives no warning of its presence. Those exposed to it do not realize it is present until symptoms begin to develop.

It is difficult to avoid some exposure to CO, because it is found in the fumes of internal combustion engines, furnaces, water heaters, fireplaces, and charcoal grills. The body also produces minute amounts of it. Inhalation of cigarette smoke is the most prevalent source of CO in the United States. The US Occupational Safety and Health Administration (OSHA) has set the maximum level for continuous exposure to CO in the home at 9 ppm and in industrial buildings at 50 ppm over an eight-hour period.

CO enters the body through the lungs and interferes with the blood's ability to carry oxygen to the body. Oxygen binds to hemoglobin molecules in the red blood cells in the oxygen-rich environment of the lungs and is released in the oxygen-poor environment of other tissues. Hemoglobin has nearly 300 times the attraction for CO as it does for oxygen. Therefore, when CO is present, far less oxygen binds to hemoglobin.

Symptoms of Carbon Monoxide Poisoning

Symptoms of CO poisoning include severe headaches, dizziness, blurred vision, nausea, vomiting, confusion, disorientation, loss of muscle control, fatigue, sleepiness, rapid heartbeat/pulse, tightening of the chest, chest pain (angina) when exercising,

fainting, and a loss of consciousness. Those affected by CO may feel ill in a CO laden environment and fine after they leave. CO poisoning proceeds in four steps. First, the blood develops less oxygen-carrying capacity as carboxyhemoglobin forms. Tissues then become starved for oxygen, especially in the brain. The respiratory center in the brain then becomes depressed which decreases respiration. Finally, if exposed to CO for long enough, heart failure may occur from an inadequate oxygen supply (Table 7.1).

Treatment of Carbon Monoxide Poisoning

Treatment of CO-induced asphyxiation must be prompt. It may be adequate to move the victim to fresh air. However, respiratory assistance and oxygen, sometimes under pressure, may be required. Air washes out half of the CO in the blood in four hours. Pure oxygen reduces this to 40 minutes. Victims should be kept quiet to minimize their oxygen requirements.

Except for its strong combination with hemoglobin, CO has no toxic effect on the body tissues. While CO does not accumulate in the body, long-term exposure can damage the nervous system if the brain is oxygen-starved. Red corpuscles are not damaged by CO, as they can transport oxygen again after they give up any CO they carry.

Who is Affected?

Carbon monoxide does not affect everyone equally. Pregnant women, people with heart problems, and children are more susceptible. Key factors that influence the speed and degree of CO poisoning include CO levels, length of exposure, age, health, weight, and sex. The gas also has a stronger effect at high altitudes where less oxygen is available.

Recommended Safe Levels/Effects of Carbon Monoxide Exposure	Definitions/Effects of Carbon Monoxide Exposure
9 ppm (0.0009%)	The maximum allowable concentration for short-term exposure in living areas, according to the American Society of Heating, Refrigeration, and Air Conditioning Engineers.
50 ppm (0.005%)	The maximum allowable US OSHA concentration for continuous exposure in any eight-hour period, according to federal law.
200 ppm (0.02%)	Slight headache, tiredness, dizziness, and nausea after 2-3 hours.
400 ppm (0.04%)	Frontal headaches within 1-2 hours. Life threatening after three hours. The maximum allowable concentration of gas according to the US Environmental Protection Agency and the American Gas Association.
800 ppm (0.08%)	Dizziness, nausea, and convulsions within 45 minutes. Death within 1 hour.
1,600 ppm (0.16%)	Headache, dizziness, and nausea within 20 minutes. Death within 1 hour.
3,200 ppm (0.32%)	Headache, dizziness, and nausea within 5-10 minutes. Death within 30 minutes.
6,400 ppm (0.64%)	Headache, dizziness, and nausea within 1-2 minutes. Death within 10-15 minutes.
12,800 ppm (1.28%)	Death within 1-3 minutes.

Table 7.1

FUELING

Fueling should be accomplished as follows. Trucks with permanently mounted cylinders/ tanks must be refueled outdoors. The exchange of removable propane fuel containers preferably should be done outdoors. If done indoors, means must be provided in the fuel piping system to minimize the release of fuel when containers are exchanged. One of the following methods should be used: An approved quick-closing coupling (a type that closes in both directions when uncoupled) in the fuel line. Close the shutoff valve to the fuel container and allow the engine to run until the fuel in the line is exhausted.

NOTE: Propane tanks are designed and constructed for filling in either the vertical or horizontal position, provided that the tank is properly mounted on the machine with the alignment pin in the proper hole. This puts the relief valve in the proper area of the tank.

Filling Procedures

Stations are to be operated only by persons who have been properly trained, know the types of fuel containers and conditions under which they may be filled, and understand proper filling procedures. The following instructions are general rules of safe procedure. They do not cover all possible situations. Additional safeguards or procedures may be necessary, depending upon the situation.

General Procedures

All combustible material should be removed within 10 feet of filling equipment. If the installation is fenced, the gates should be opened. Smoking, open flames, and sources of ignition should not be permitted within 25 feet of the filling operation. There are to be no passengers in the vehicle during fueling. If scales are used for container filling, they should be calibrated with test weights daily.

Propane is distinctly odorized. Anytime the station is unattended, the liquid outlet valve and bypass return valve on the storage tank must be closed. The hose should be coiled on a rack inside a protected area. The protected area must be locked to secure installation against tampering.

Filling Procedure: Portable Propane DOT Cylinders by Weight

First, the tank must be inspected. The legal filled weight of the tank should be calculated and the scale should be set to indicate this weight. The tank needs to be weighed to determine how full it is. Next, the liquid outlet valve and bypass return valve need to be opened on the storage tank. The protective plug in the fill valve must be removed before the hose can be connected to the tank fill valve. After the pump is started, the tank valve must be opened as the valve on the end of the hose is slowly opened. As the scale beam tips, the hose and tank valves must be closed prior to turning off the pump. Next, the bleeding off pressure of the hose should be slowly disconnected. After filling, the weight of the tank needs to be checked. The tank must not be overfilled. Adequate vapor space must be left in the tank to allow for the expansion of liquid. Excess liquid should be bled off in a safe location. Finally, a protective plug should be provided in the valve opening.

Filling Procedure: Propane ASME Tanks or Portable DOT Tanks with Fixed Liquid Level Gauges

First, the tank must be inspected and the meter register "zeroed". Before the filling procedure can be started, the propane in the container must be checked to determine the level. This can be done by observing the discharge from the vent valve of the fixed liquid level gauge. A cloud of visible

vapor indicates a filled container. Next, the liquid outlet valve and bypass return valve need to be opened on the storage tank. The protective plug in the fill valve must be removed before the hose can be connected to the tank fill valve. After the pump is started, the vent valve of the fixed liquid level gauge must be opened. If the container fill valve is hand-operated, the valve must be opened. Some open automatically when connected or when filling begins. The valve on the end of the hose should be slowly opened and filling should occur until the propane coming from the vent valve is visible. The hose end valve and fixed liquid level gauge vent valve must then be immediately turned off. The container must not be overfilled. Adequate vapor space must be left in the tank to allow for the expansion of liquid. Excess liquid should be bled off in a safe location. If hand-operated, the container valve needs to be turned off prior to turning off the pump. Next, the bleeding off pressure of the hose should be slowly disconnected. Finally, a protective plug should be provided in the valve opening.

CNG Filling

Before refueling can begin, the method the refueling system used to refill the cylinder has to be determined. There are two methods employed. The first is timed-fill, also known as slow-fill, and the second is known as fast-fill. Timed-fill is where the machine is connected directly to the compressor and the refueling process takes several hours to fill the cylinder. The time taken depends on the size of the compressor and the volume of the cylinder being refueled, normally the machine is refueled overnight. The advantage to this method is it is the low-cost method for refueling with CNG. The second method is known as the fast-fill method. Gas is stored in holding tanks at 5,000 psi. These tanks, known as a cascade, deliver fuel into the fuel tank in about the same time as it

takes to fill the equivalent volume of gasoline. The procedure for filling from either method is the same.

Propane DOT Tank Visual Inspection

All cylinder identification markings must be legible. Only those DOT (formerly ICC) tanks should be filled: 4B-240, 4BA-240, 4BW-240, 4E-240 and 26-300. The test date stamped on the tank must be within the required retest or requalification date. Government regulations (49CFR 173.34) require retest or requalification within the following dates:

- 12 years after manufacture;
- 12 years after the latest test date (typical mark, 6-88);
- 7 years after the latest test date when followed by an S (typical mark 6-88S; or
- 5 years after the latest test date when followed by an E (typical mark, 6-88E).

Tanks cannot be refilled after retest comes due and until requalified.

The tank should then be examined to insure it is not gouged, dented, been exposed to fire, or is not excessively corroded. The bottom ring should be checked to see if it will support the tank in a stable upright position. In order to prevent damage to valves, only those tanks which have required protective caps or guards should be filled. The pressure relief valve discharge outlet needs to be inspected for blockage and obstructions. All seams, openings, and valves should be checked for leaks. Filling a leaking or damaged tank violates regulations.

Calculations Required When Filling DOT Tank by Weight

Scales that are used for tank filling should be checked with test weights daily to verify calibration. Check the empty weight of tank (tare weight or TW) and water weight capacity (WC) stamped on the tank body near the valve or protective collar. TW does not include the weight of the removable cap. The propane weight can then be calculated in pounds by multiplying water WC by .42 or by using values from the following table (Table 8.1).

Water Capacity (lbs.)	Equivalent Propane Capacity (lbs.)
12	5
24	10
48	20
60	25
144	60
239	100

Table 8.1

The weight can then be determined by placing the hose connector and hose end valve on the scale. This is the weight that should be referred to when filling by weight. Empty tank weight, propane weight, and hose assembly weight can then be added to determine the legal filled weight of the cylinder. Example: TW = 70 lbs.; WC = 239 lbs.; Weight of hose assembly = 5 lbs.

Legal filled weight =
TW +(WC x 0.42) + Hose assembly weight =
70 + (239 x 0.42) + 5 = 70 +100 + 5 = 175 lbs.

ASME Tank Inspection

ASME data plate markings must be checked. These ASME tanks should be filled with a maximum allowable working pressure (MAWP or MWP) of 250 psig or greater. If the tank is in an enclosed space or used on industrial trucks or forklifts, MWP must be 312.5 psig or greater. The tank should be visually inspected to insure that it is not gouged, dented, bulged, exposed to fire, and is not excessively corroded. A leaking or damaged tank should not be filled and doing so violates regulations.

NOTE: This section will deal with principles and general procedures that will give the technician an understanding of how to diagnose engine condition and to determine what component is at fault. The manufacturers service manual should be referred to for component repair and procedures.

Basic Maintenance Tools:

Hand wrenches
Pressure gauges
(1) 0–20 psi. (2) 0–250 psi. (3) 0–5000 psi.
Manifold vacuum gauge
Leak detection solution
Exhaust gas analyzer

Hose Installation

The high pressure fittings that are installed on the ends of the hose, must be SAE flare fittings and have a 45 degree flair. Hydraulics use a JIC fitting which has a 37 degree flare and will not properly seat to the base fitting. These fittings are not interchangeable. The nut of the propane fitting has an identifying notch that the JIC fitting does not have and is labeled SAE.

When installing the hose ends, the proper length should be marked on the hose. If the hose is being connected to one device that is mounted on the frame to another one which is mounted on the engine, extra hose should be allowed for engine movement. A hose should never be stretched too tight. When the fittings are installed on the end of the hose, it adds about 2 inches to the length—about 1 inch per fitting.

Because of the wire braid, a hacksaw must be used to cut the hose. Side cutters can be used to cut away any protruding ends. This is important because of the way that the fittings lock together. The outer female part of the end fits onto the end of the hose by turning it counterclockwise. The turning

is stopped when the end of the hose seats flush against the inside lip of the fitting. The hose at the base of the nut should be marked in order to detect if it gets pushed out as the male fitting is installed.

Next, the male portion of the fitting is installed. A lubricant should be used to facilitate installation. The inner wall should not be cut when installing this part. It can cause a blockage of fuel or a leak. This fitting turns clockwise. If turned too far, the fitting may break off. When the nut of the male section touches the female section, it is tight enough. The mark on the hose should then be checked to make sure that it did not push out of the fitting.

Be careful when using Teflon tape. Start about one thread from the end and wrap the tape in the same direction as the threads. Do not use an excessive amount of tape. The excess tape that gets cut off when inserting the fitting can travel through the propane system and lodge under the seat of the lockoff or the primary seat of the regulator. This can cause gas to bleed through the system and presents an unsafe condition.

When installing a liquid line where two tanks are connected together, a spring-loaded backflow check valve must be installed. The valve should be located before the point where the liquid lines tee together in order to prevent the transfer of propane from one container to another.

If it is necessary to route a line through sheet metal, drilling a hole and passing the hose through will cause the hose to get chafed and could result in a fuel leak. A rubber grommet or bulkhead fitting must be used. The line must be secured and positioned away from any heat source. A heat shield can be fabricated to protect the line. Remember that heat causes the propane pressure to increase. The piping

must be designed, installed, supported, and secured in a manner to minimize the possibility of damage due to expansion, contraction, vibration, strains or wear.

The stainless, reinforced aeroquip type hose may be used in any length. Propane hose must be labeled and visually marked for propane with a working pressure of 350 lbs and a burst pressure of 1,750 lbs. The brands of hose and fittings should match or be at least compatible.

Safety

When storing tanks inside a building, there can be no more than 300 pounds of propane, or 8.9 tanks, at one spot (NFPA 58, page 53, paragraph 5-3.2). Additional tanks must be stored 300 feet away. An empty tank is considered the same as a full one for this purpose.

Garaging and Storage of Machinery

Alternatively fueled machinery may be garaged anywhere gasoline-powered vehicles are garaged. When machines are to be stored for a long period, it is advisable to shut off the tank supply valve and run the machine until the fuel trapped down stream of the valve is depleted. NFPA 52 and 58 cover the procedures for storage and garaging for repair purposes on natural gas-and propane-powered equipment.

Shop Safety

Safety is an important consideration for any repair facility, and repairing alternatively fueled machinery is no exception. Fire extinguishers should be Class B:C 20#.

Drop lights should be safety fluorescent and a gas detection alarm system should be in place. When repairing propane machinery, they should be in the lowest point of the

facility. Natural gas requires them to be placed in the highest portion of the building.

The tank supply should be shut off, except when required for running equipment.

Verifying Engine Condition

There is a common saying among veterans of the alternative fuel industry. It is "the flat tire syndrome." That is, the fuel system is the cause of every failure including a flat tire. The opposite is generally the case. The first steps are to eliminate the obvious.

Ignition System

Propane and natural gas fuels require greater electrical energy for proper ignition. What may be acceptable for gasoline may not be acceptable for the gaseous fuels. (Refer to fuel properties chart.) If a no-start or poor running condition exists, a test spark plug should be used. A test plug can be made or purchased by doubling the gap and welding a ground clamp on the side of the plug. Removing a spark plug, attaching the high tension plug wire to it, and holding the plug against the engine block, and observing if a spark jumps the gap as the engine cranks over may not correctly diagnose a secondary ignition. Even if a spark occurs, it may not have sufficient energy to jump the gap when compression pressures and the fuel mix are present.

NOTE: The fuel system should be disabled when cranking the engine with spark plugs removed. This prevents ignitable air/gas mixtures from being introduced into the engine compartment. Many forklift ignition systems still use breaker points. In this case, they should be checked to see if they are burned or pitted. The point gap and play in the center shaft of the distributor should also be checked.

Spark plug gaps should be checked and should be within the manufacturer's specifications. In the past, it was recommended to close-up plug gaps when using propane and natural gas; this was done to overcome the ignition coils inability to generate sufficient voltage to jump the spark plug gap. The modern gasoline engine requires more secondary voltage than their older counterparts, the result being ignition coils have sufficient energy to lightoff gaseous fuels without closing the plug gap. Closing spark plug gaps down may cause exhaust hydrocarbons to rise.

Always make sure that the ignition coil has the correct primary voltage during cranking and while running. When possible, a colder spark plug should be used when operating on a gaseous fuel. When an engine is running on gasoline, gasoline continues to vaporize as it enters the combustion chamber. Gasoline absorbs heat from everything it touches in the vaporizing process. To compensate for this cooling action across the tip of the spark plug, the heat range of the spark plug on the gasoline engine has been raised. Propane and natural gas enter the combustion chamber as vapors and normally do not require a hot plug. If spark plugs have failed prematurely, and there is no sign of oil contamination, the spark plug heat range can be lowered to increases plug life.

Ignition Timing and Adjustment

Ignition timing requirements are different for gaseous fuels than gasoline. Propane and natural gas have higher octane numbers than gasoline. The higher the octane level, the slower the fuel burns.

There are three different considerations to think about with ignition timing.

1. initial timing. This occurs at idle in relationship to the crankshaft degrees before top dead center (TDC).
2. the flyweight curve, which is ignition timing mechanically advanced by increased RPMs.
3. the vacuum advance system, which gives a higher rate of advance for part-throttle. Each distributor should be checked for total advance with an adjustable timing light.

Heavy duty operations require fully advanced ignition by 2000 to 2200 rpms. If spark lead is not advanced enough, combustion will occur so late in the combustion cycle that the fire will still be burning when the exhaust valve opens. Exhaust temperatures climb steadily until they result in the cracking of the exhaust manifold and burning of the exhaust valves. Should the exhaust valve itself become hot enough to ignite the incoming charge, backfiring will develop. Such destructive effects, due to under-advancing the spark, will also be accompanied by poor fuel consumption and loss of horsepower. Over-advanced timing will increase Nox emissions levels.

Engine mechanical condition should not be overlooked. Check for vacuum leaks. A rough running engine may indicate vacuum hoses have fallen off. It is usually a good idea to spray a compound around the carburetor base plate and intake manifold area to check for vacuum leaks. Also, a dry and wet compression test or a cylinder air pressure test should be taken.

Once assured that the other engine systems are in good operating condition, the propane system may be checked. When using proper methods, the complete

propane system can be tested in about 15 to 20 minutes.

Diagnosing Performance Issues

NO Start — possible causes:

1. Ignition system
2. Engine mechanical condition
3. Fuel system:
   a. No fuel
   b. Faulty lockoff
   c. Vacuum or oil safety switch faulty
   d. Incorrect system wiring
   e. Faulty regulator
   f. Lean or Rich fuel mixtures

No Fuel

Check fuel level by observing fuel gauge or tank pressure gauge. If there is no gauge in a propane tank, the safest method is to remove tank and check its weight or open the liquid-level valve and monitor any discharge.

Faulty Lockoff

If it is vacuum operated, remove the vacuum hose and apply a vacuum using a vacuum hand pump. Confirm that the fuel lockoff will hold a vacuum. If so, is fuel flowing to the regulator?

Vacuum or Oil Safety Switch Faulty

Once it is confirmed that fuel is at the fuel lockoff, check lockoff function.

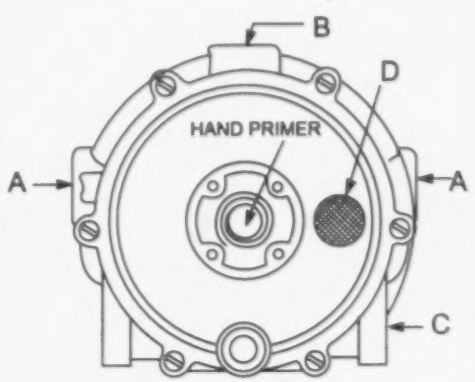
Confirm that electrical current is at the lockoff during cranking. If not, check vacuum or oil pressure safety switch operation.

Faulty Regulator

Most regulators have a port for testing the pressure at the primary section of the vaporizer/regulator. Some regulators have an 1/8 inch pipe threaded plugs that require a 7/16 wrench to remove. Connect

MAKE	MODEL	PRIMARY	SECONDARY
IMPCO	JB-LB-EB	1-11/2 PSI	1½" NEG W.C.
IMPCO	JO-LO-EO	1-11/2 PSI	1½" NEG W.C.
CENTURY	G 85	5 - 7 PSI	1½" NEG W.C.
CENTURY	H-HV	4 - 6 PSI	1½" NEG W.C.
CENTURY	M4-M5-M6	5 - 8 PSI	1½" NEG W.C.
BEAM	50 - 60	4 - 5 PSI	
BEAM	100 - 200	4 - 5 PSI	
ALGAS	1900 -1950	4 - 6 PSI	
ALGAS	C250 SERIES	1 - 11/2 PSI	
J&S	B1-B2	10 - 12 PSI	
J&S	AB 10	10 - 12 PSI	
J&S	11A SERIES	8 - 10 PSI	
J&S	60B00/600	(IN. NEG W.C. ON DEMAND)	
ZENITH	A962A-1A	10 - 12 PSI	
ZENITH	A965A	10 - 12 PSI	
ZENITH	A806-43	2 PSI	
GARRETSON	(AS SPECIFIED ON EQUIPMENT)		

Table 9.1



CONVERTER SPECIFICATIONS

A COOLANT INLET AND OUTLET NPT
B LIQUID FUEL INLET NPT
C VAPOR FUEL
D VENT BALANCE LINE CONNECTION NPT

Figure 9.1 Converter

a 0-20 psi gauge to the port and crank the engine. Primary pressure should be within the manufacturer's specifications (see Table 9.1).

Next, confirm that fuel is available to the gas mixer, the hose supplying fuel to the mixer is disconnected, and regulator primer activated to check fuel delivery (Figure 9.1).

Air/Fuel Mixtures

That are too lean or too rich will prevent a engine from starting. Check for a residue buildup in the vaporizer/regulator and gas mixer. This residue takes a set and has a waxlike appearance when cold; this can prevent the proper functioning of these components, causing incorrect fuel mixtures.

System By-Products

When inspecting a propane vaporizer/ regulator mixer or carburetor, a certain

GPA LIQUEFIED PETROLEUM GAS SPECIFICATIONS		
Product Designation	**Commercial Butane**	**Propane HD-5**
Composition	Predominantly propane and/or propylene	Not less than 90 liquid volume percent propane; not more than 5 liquid volume percent propylene.
Vapor Pressure at 100 F, psig max.	208 degrees	208 degrees
Volatile residue:	-37 degrees	-37 degrees
temperature at 95% evaporation deg. F, or	2.5	2.5
butane and heavier, liquid volume percent	—	—
pentane and heavier, liquid volume percent		
Residual matter:		
residue on evaporation of 100 ml, max.	0.05 ml	0.05 ml
oil stain observation	pass (1)	pass (1)
Corrosion, copper strip, max	No. 1	No. 1
Total sulfur, ppmw	185	123
Moisture content	pass	pass
Free water content	—	—

Table 9.2

amount of heavy ends or by-products will be found in the system. HD5 Grade propane is recommended for motor fuel use. However, HD5 propane will carry a certain amount of heavy ends (Table 9.2).

Propane is a by-product of crude oil and natural gas. In the extraction process various hydrocarbons are separated; products such as gasoline, kerosene, oil, propane, butane,

and diesel fuel are developed. None of these products are perfectly pure; these are heavy ends. Each of them carry a certain amount of by-product residues. Under normal circum-stances, these residues remain in liquid form and pass through the system undetected.

Engine coolant flows through the vaporizer/regulator assisting in the propane vaporization process. As the coolant temperature rises, the vaporizer/regulator temperature rises also. The gas becomes hot and expands to the point where it cannot carry the heavier hydrocarbons and drops them into the vaporizer/regulator. When they cool they become a waxlike sludge. Some manufacturers provide an opening in the regulator to drain out this product. A fuel filter cannot remove this, as it is not a dirt but a part of the liquid propane. In order to solve this problem, the technician can do one of two things. One, the vaporizer-regulator can be remounted as high and as close to the carburetor as possible. In this position, the substance will pass through the mixer for combustion. Second, an in-line thermostat can be installed in the regulator coolant line. This will keep the coolant temperature at 110 degrees Fahrenheit at the vaporizer-regulator and eliminate most of the sludge buildup.

Hard Starting:
possible causes

1. Ignition system, system condition and ignition timing
2. Engine mechanical condition
3. Fuel system:
    a. Faulty lockoff
    b. Vacuum or oil safety switch faulty
    c. Incorrect system wiring
    d. Faulty regulator
    e. Lean fuel mixtures/rich fuel mixtures
    f. Throttle in the incorrect position during cranking

The procedure for diagnosing a hard-start condition is similar to the no-start condition; but there are some differences, which are the focus in this section.

First, follow the no-start procedures. If these procedures do not indicate any failures, then, check idle fuel mixtures. It is best to use a four-gas exhaust gas analyzer for this procedure (discussed in the chapter on exhaust emissions).

Cold Starting

Gaseous fuels pose slightly different problems for fast cold-starts than a conventional gasoline fuel system. An explanation of what happens when a vehicle shuts off will help understand what steps to take to correct a poor cold-start (Table 9.3).

As was discussed in the chapter on fuel system operation, a major difference with a gaseous fuel system is that the major components are separated in the engine compartment. The vaporizer/regulator, acting as a carburetor float system, is separated from the gas mixer. When the engine shuts off, gas is trapped in the gas delivery hose connecting the mixer to the regulator. As the engine cools down, the gas in the hose contracts and air from the engine is drawn into the gas hose. When the engine is cranking to restart, the air has to be purged from the system before the engine will start. A similar situation occurs when you attempt to light a propane Bar-B-Q grill after replacing the tank.

Simulating Cold Starting

Most cold starting problems are caused by incorrect installation or an inadequate ignition systems. In many cases, after the engine is started and warmed up, it will restart satisfactorily during the day even if the weather is quite cold. Therefore, a first

PROPANE VAPOR PRESSURES AT VARIOUS TEMPERATURES	
Degrees F.	**PSIG**
-20	10.7
-15	13.6
-10	16.7
-5	20.0
0	23.5
5	27.2
10	31.3
15	35.9
20	40.8
25	46.2
30	51.6
35	57.3
40	63.3
45	69.9
50	77.1
55	84.6
60	92.5
65	100.7
70	109.3
75	118.5
80	128.1
85	138.4
90	149.3
95	160.3
100	172.3
105	185.3
110	197.3
115	211.3
120	225.3
125	239.3
NOTE: All pressures are based on a specific gravity of 1.53.	

Table 9.3

morning start up problem can be hard to troubleshoot. In a properly functioning gaseous fuel system, the starting time required is approximately one second for every one-foot length of gas hose between the fuel regulator and the mixer.

NOTE: Mounting the regulator as close as possible to the mixer can alleviate this condition.

To simulate first-morning start up, disable the gas lockoff, loosen the hose clamp on the fuel regulator end of the gas hose, and remove the gas hose at the fuel regulator. Crank the engine. The inertia of the engine will pull all of the gas from the mixer and the and hose and replace it with air. To insure that there is no fuel left in the engine or mixer, reconnect the hose, crank the engine with the throttle partly open to determine start up time.

Inadequate Engine Performance:
possible causes

a. Ignition system
   - Timing
   - misfire

b. Engine condition
   - Restricted air cleaner
   - Restricted exhaust

c. Fuel system
   Lean or Rich Mixtures
   - Vaporizer/ regulator freeze-up
   - Blocked fuel filter
   - Incorrect fuel withdrawal connection or tank
   - Low regulator pressures
   - Regulator atmospheric vents restricted or plugged
   - Mixer air flow capacity mismatched to engine capacity

Lean or Rich Mixtures

The procedure for adjusting fuel mixtures fuel mixtures will be addressed in the chapter on emissions.

Vaporizer/Regulator Freeze Up

Regulator freezing will occur if engine coolant fails to circulate the heat exchanger portion of the vaporizer/regulator. Confirm correct coolant circulation. Coolant will not flow through the vaporizer if taken from the same side of the coolant flow. One end must be connected to the block (pressure) and the other to the water pump area (return). In most cases, the coolant flows through the complete vaporizer. When starting an engine in cold temperatures, the vaporizer/regulator will begin to freeze if the water flows directly through a pipe.

Blocked Fuel Filter

A fuel filter can get plugged up with tank slag—a gray metal-like substance that comes from the inside of steel propane tanks. The key indicator that this is occurring is freezing at the fuel filter when the engine is at full load.

Incorrect Fuel Withdrawal Connection or Tank

A engine can loose maximum power if it is connected to the vapor side of a propane tank when liquid withdrawal is required. The surface area of the propane tank is insufficient to vaporize sufficient fuel to meet engine demands. An indicator of this is condensation appearing on the tank surface.

Low Regulator Pressures

The High pressure regulator in a CNG system must be set to allow sufficient fuel pressure to the low pressure regulator for maximum power requirements. Check the outlet pressure at the inlet to the low pressure regulator. This check should be carried out at idle and at full power. If there is a

large pressure drop between these two readings, the high pressure regulator may need servicing or readjusting.

Regulator Atmospheric Vents Restricted or Plugged

A regulator must have a vent to the atmosphere in order to set up a differential pressure on the secondary diaphragm. Many machines have this vent connected to the air cleaner side of the mixer to correct incorrect fuel mixture calibration caused by air flow restrictions in the air cleaner. If the regulator vent is restricted or blocked, the incorrect difference in pressure in the secondary side of the regulator will cause the regulator not to deliver sufficient fuel to meet engine demands.

Mixer Air Flow Capacity Mismatched to Engine Capacity

The gas/air mixer must have sufficient capacity to meet engine air flow requirements. Many conversions are after market conversions, and the possibility of an incorrect mixer application can arise. Air flow is a function of engine cubic inch displacement and maximum RPM. The formula for calculating maximum air flow is: CID x RPM / 1728 / 2 = Max. air flow. Refer to the manufacturer's catalog or service manual to verify mixer application.

Testing

The opening statement of this manual emphasized government regulations, especially OSHA requirements for indoor air quality. In the chapter on health and safety we discussed the affects of carbon monoxide poisoning on the human body. Even though most materials handling equipment using internal combustion engines are fueled by propane or natural gas, correctly setting the air/fuel mixture is essential to ensuring proper indoor air quality (Figure 10.1).

Examples 1 and 2 below are indications of the important role the correct air/fuel mixture settings play in indoor air quality.

Example 1: A forklift with a150 cu./in. engine running at 2,000 rpm full load will consume approximately 75 cu./ft. of air in 1 minute or 4,500 cu./ft. per hour.

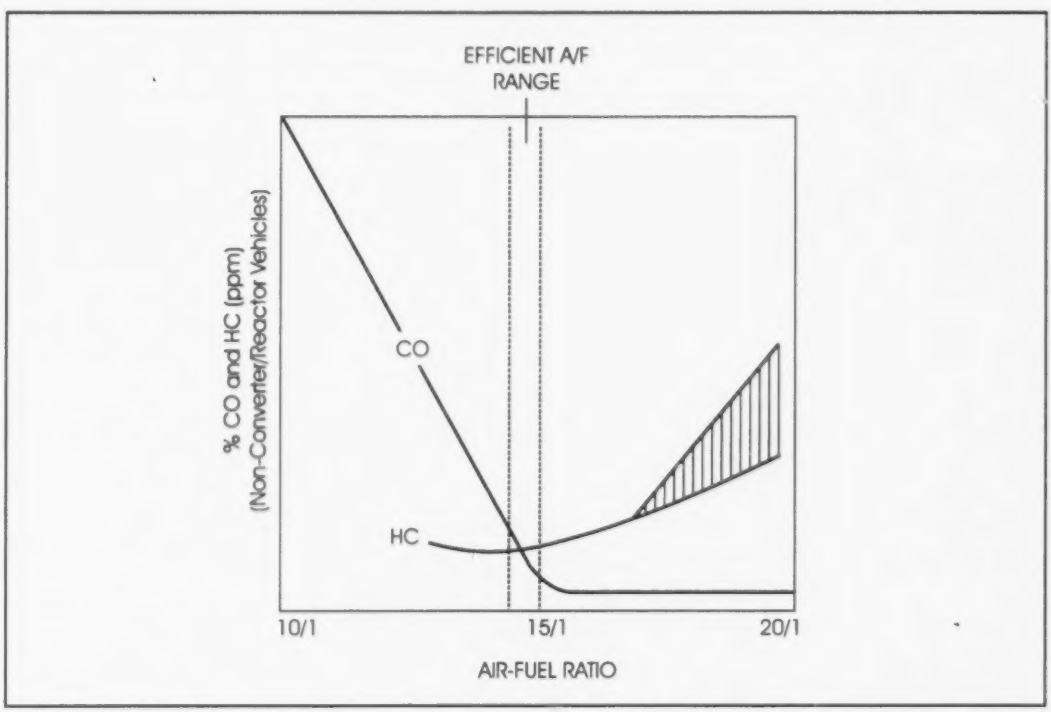


Figure 10.1 Exhaust Gas Composition

If the exhaust CO reading is 1 percent, the forklift would produce 45 cu./ft. of CO in one hour.

A warehouse 100' x 100' x 20' contains 200,000 cu./ft. of air.

OSHA standards allow a maximum of 50 ppm (parts per million) of CO in the factory's air, (which is 0.00005% of 200,000 = 10 cu./ft. of CO), it will take 13.3 minutes to contaminate the warehouse above OSHA standards.

Example 2: Same initial information as in Example 1, but the exhaust CO reading is 0.2 % CO. The machine will now produce 9 cu./ft. of CO in one hour and it will take 1 hr./6 min. to reach allowable standards for CO.

These examples did not allow for replacement air entering the building. Also, it is highly unlikely that a forklift would operate in a full-power condition for the lengths of time noted in the examples. Nevertheless, the examples do illustrate how important the mixture setting is to air quality conditions. The main exhaust gas components a technician should be concerned with when checking and setting fuel mixtures follow.

Carbon Monoxide (Co) Hydrocarbons (HC) and Oxygen (0_2)

Carbon Monoxide

Carbon Monoxide is a indicator of how rich or lean air/fuel mixtures are. It is formed as a result of imperfect combustion. When hydrocarbon fuels burn completely, carbon dioxide and water vapor form. When they burn incompletely, due to insufficient oxygen, CO and other chemicals are formed. Most repair grade analyzers measure CO in percent (%) by volume. 1 percent CO means 1 percent of the total 100 percent of the exhaust gas consists of CO (Figure 10.2).

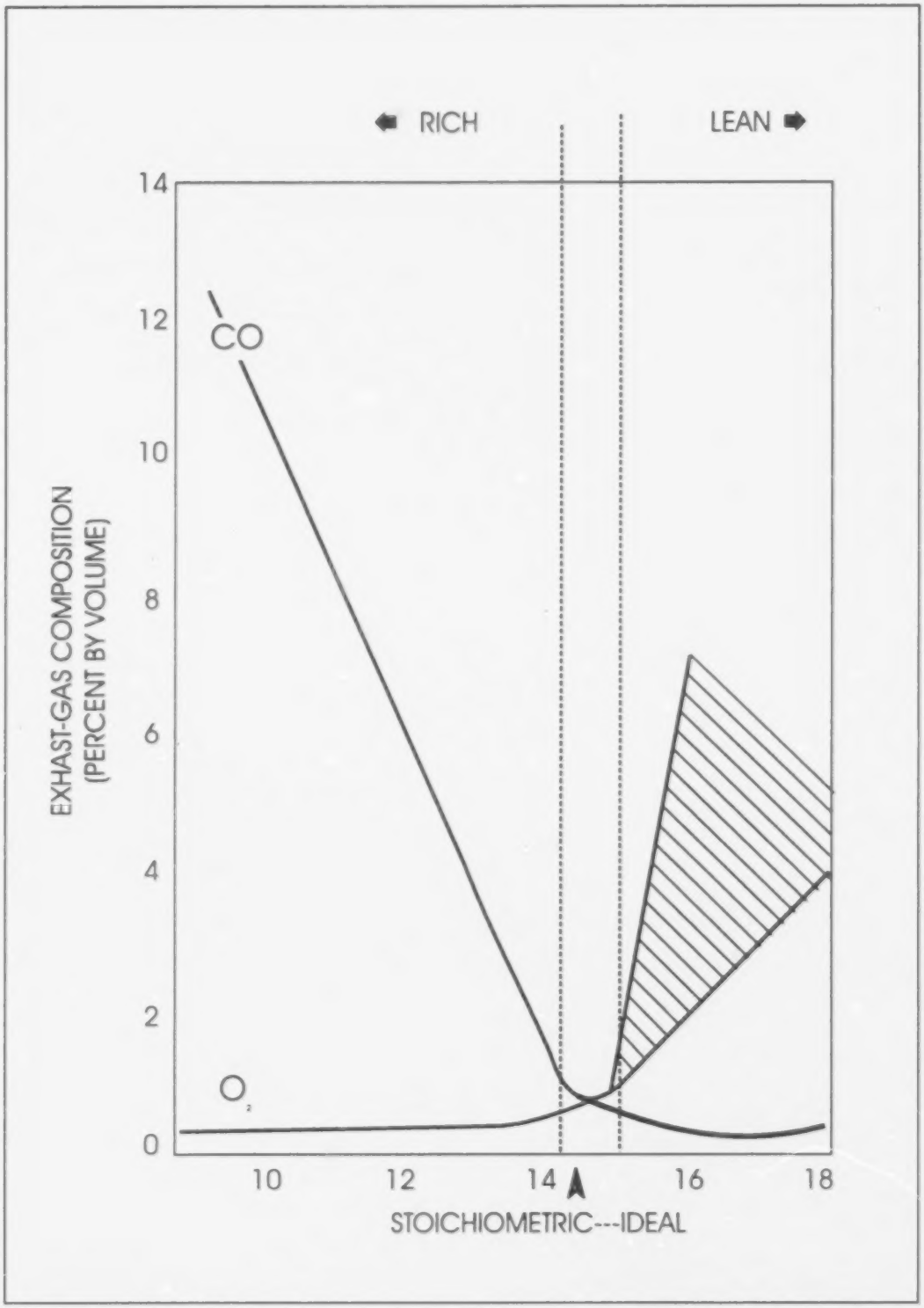


Figure 10.2 Efficient Air Fuel

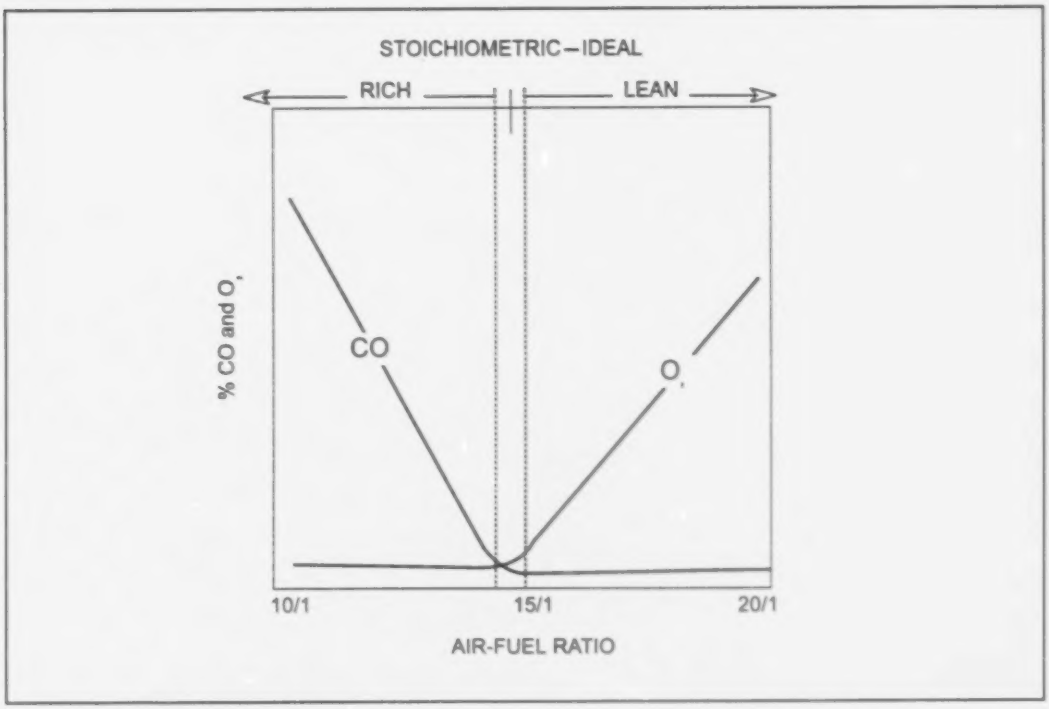


Figure 10.3 Stoichiometric Ideal

Hydrocarbons

Hydrocarbons (HC) are an indicator of how complete the combustion process is. HC is low when the air/fuel mixture is correct. It will rise if the mixture is too rich, causing incomplete combustion or too lean, causing partial misfire and incomplete combustion.

It can also give an indication of ignition system performance and engine mechanical condition. HC is measured in parts per million (ppm) by volume.

Oxygen

Oxygen (0_2) in the exhaust is an indicator of how lean the air/fuel mixtures are. 0_2 will increase in proportion with the air/fuel ratio. As fuel mixtures get richer, 0_2 readings are low and CO readings are high. A lean condition will show high 0_2 and low CO. Like CO, it is measured in percent (%) by volume (Figure 10.3).

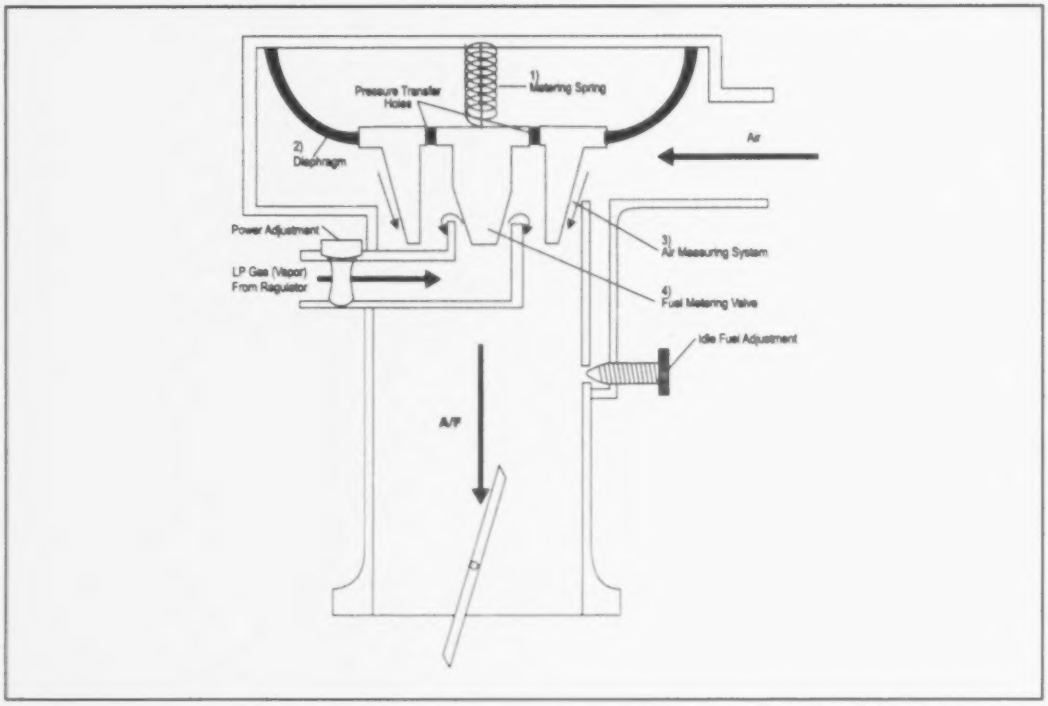


Figure 10.4 LP Gas Air Valve Carburetor

As stated in previous chapters of this module, a gaseous fuel system (Figure 10.4) carries out the same functions as a gasoline carburetor does (Figure 10.5). To install a rebuilt gasoline carburetor, the setup procedure would be as follows:

1. set the float level;
2. set the Idle mixtures;
3. check main jet;
4. power valve settings; then
5. adjust the choke.

The procedure for a gaseous fuel system are:

1. set regulator pressures and lever height settings;
2. set idle mixtures;
3. check and adjust part-throttle mixtures; and
4. set full-power mixtures.

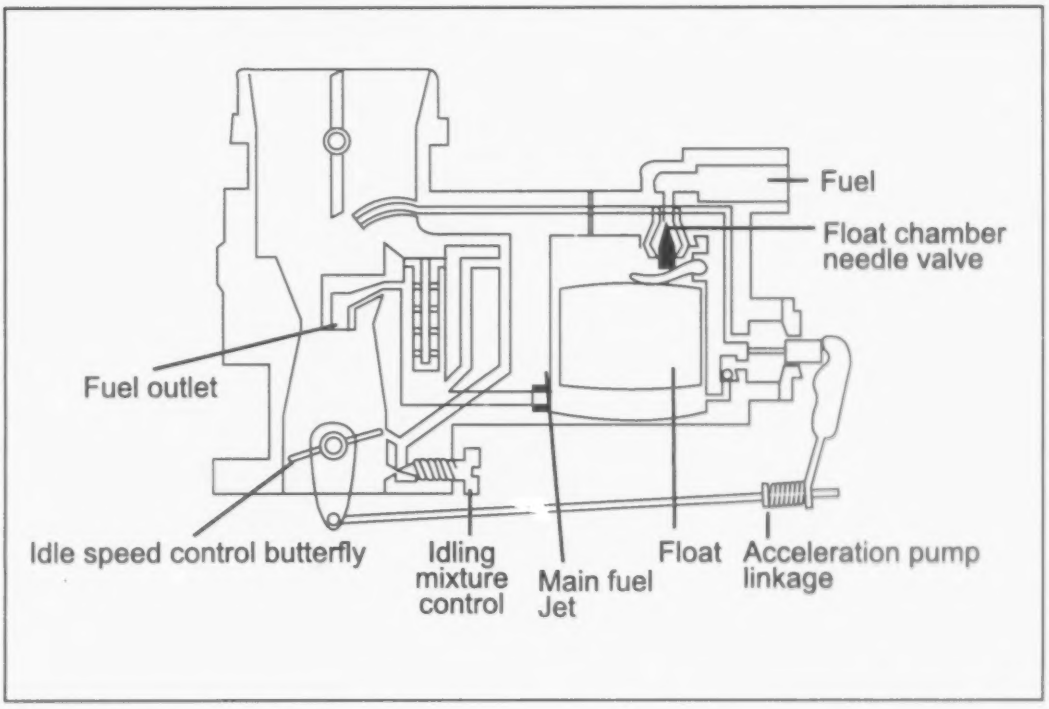


Figure 10.5 Carburetor Cutaway

The mixture pattern graphic gives an indication of what the CO reading would look like through the complete operating range of the engine. It is possible to have excellent idle and power mixtures settings and yet the part-throttle mixtures are rich (Figure 10.5). This results in unacceptable emission levels, leaving the technician uncertain as what to do next. When there is no record of the machine's history (Table 10.1) or exhaust emissions, it is essential to follow the procedure listed below.

Checking Exhaust Emissions

Tools required to check exhaust emissions include:

1. infrared four-gas exhaust analyzer, preferably portable 12-volt operated;
2. manifold vacuum gauge; and
3. engine tachometer.

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Engine condition	Engine RPM	Engine manifold vacuum	Carbon Monoxide CO (%)	Hydrocarbons HC (ppm)	Exhaust Oxygen (%)
Idle					
Max rpm					
Part load					
Tilt relief					
Engine stall					

Table 10.1

Verify ignition condition; check and set ignition timing; verify engine mechanical condition (valve clearances, PCV valves, etc).

The engine should be at operating temperature. It is best to prepare a chart as follows:

1. Take readings at idle.
2. Maximum governed, no-load RPM.
3. Part-load. Chock wheels; apply parking brake; bring engine up to 2,000 rpm; apply some load (apply tilt relief) until approximately 10" Hg manifold vacuum.
4. Tilt relief; bring engine up to maximum RPM; apply tilt until hydraulics pressure bypass; take readings.
5. Place machine in drive; WHEELS CHOCKED; PARK BRAKE ON; take a reading at full-load; engine stall.

Engine condition	Engine RPM	Engine manifold vacuum	Monoxide CO (%)	Hydrocarbons HC (ppm)	Exhaust Oxygen (%)
Idle	592	17	.31	23	11.1
Max rpm	2610	15.5	1.87	37	.6
Part load	2000	10	1.69	44	1.5
Tilt relief	2470	0	1.31	44	1.2
Engine stall	1687	0	.25	35	2.9

Table 10.2

The following example is from an actual field test.

TEST 1

This test revealed that emission levels were satisfactory at idle and engine stall but the mid-range mixture was unsatisfactory (Table 10.2).

The mixture pattern illustrates the problem. If you consider engine air flow at idle verses the part-throttle air flow, correctly set idle mixture has less affect on total indoor air quality than does the part-throttle mixtures, and a serious health problem would arise, if the machine were operated indoors (Figure 10.6).

Correcting Part-Throttle Mixtures

Correcting part-throttle mixtures will depend on the type of fuel system being used. Manufacturers of venturi systems normally offer a vacuum operated power valve that will allow part-throttle and power mixtures to be correctly set. Air valve systems rely on the profile of the metering valve to govern part-throttle mixtures. A valve with a different profile will be necessary to solve the problem. Manufacturers offer different profiles for

S9

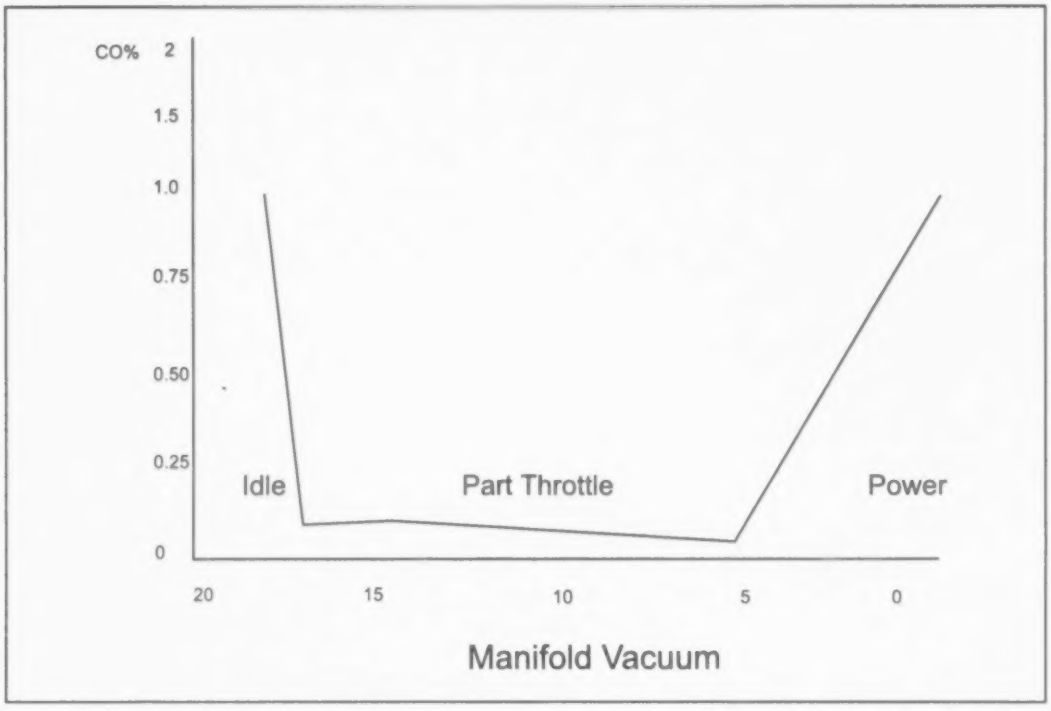

Figure 10.6 Ideal Mixture Pattern

different engine applications, or shims are placed between the fuel valve and air valve to correct this problem (Figure 10.7).

NOTE: Before making any changes, check to make sure that the correct spring is in the secondary side of the regulator. A soft spring would give the affect of having the float level set high on a gasoline carburetor; a stiff spring would have the opposite affect.

On occasions, some manufacturers have installed a balance line between the atmospheric vent of the vaporizer/regulator and the mixer air inlet to compensate for air flow restrictions caused by the air cleaner. If a balance line was originally installed, removal of the line can cause rich part-throttle mixtures.

EXHAUST EMISSIONS

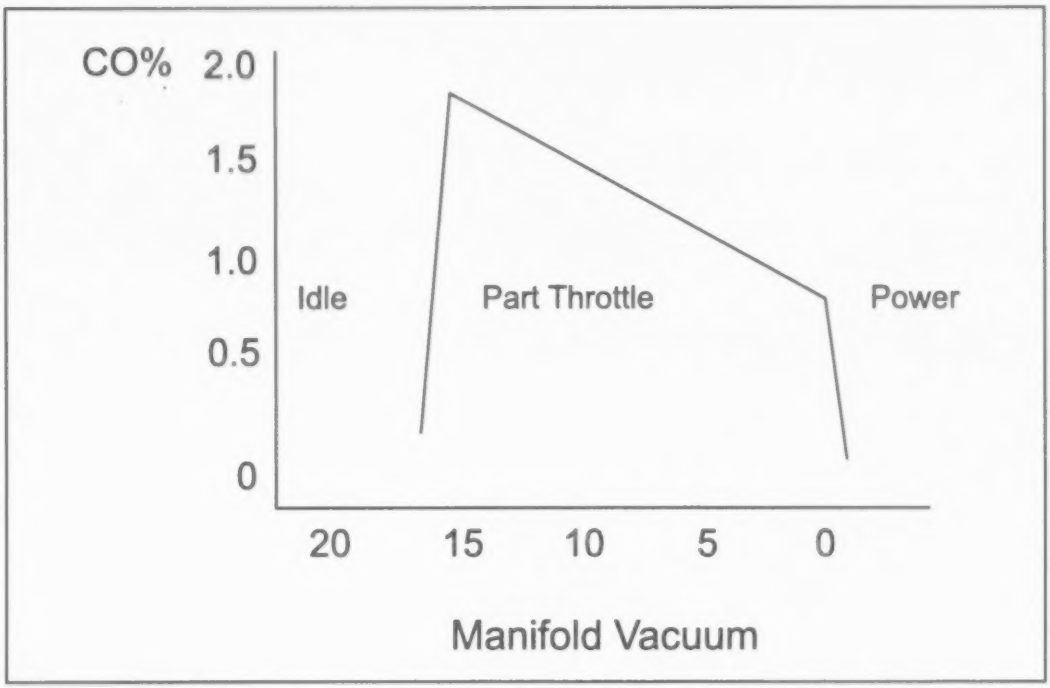

Figure 10.7 Mixture Pattern

Engine condition	Engine RPM	Engine manifold vacuum	Carbon Monoxide CO (%)	Hydrocarbons HC (ppm)	Exhaust Oxygen (%)
Idle	647	17	.04	60	12.2
Max rpm	2590	13	.06	40	3.5
Part load	2000	10	.05	35	4.9
Tilt relief	2350	5	.04	40	3.5
Engine stall	1670	0	1.00	65	0

Table 10.3

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Power Mixtures Settings and Emissions

Referring to the Ideal mixture pattern (Figure 10.5), you can see that mixtures should get richer when the manifold vacuum falls below 5"-3" Hg. This mixture should be set to give maximum power with the lowest possible emissions. It should only be set when the engine is in load and the manifold vacuum is below 5" Hg (Table 10.3).

Compare the results in Test 1 to Test 2 (Table 10.2 and Table 10.3). Notice that the CO mixtures are low from idle all the way through tilt relief, then get richer under stall conditions. Consider the HC emissions. Notice that HC are higher in test 2. This indicates that the mixtures are a little lean from idle through tilt relief and slightly rich at stall.

TEST 2

Tests 3 and 4 are the results of testing using instruments and procedures similar to those required by the EPA for emission certification by vehicle manufacturers. The tests lasted for 14 minutes. The results are shown in grams per test. The mixture settings for test 3 were the same as test 1, and the mixture settings for test 4 were the same as Test 2 (Table 10.4).

	Test 3	Test 4
Emission		
Hydrocarbons	6.04	4.00
Nitrogen oxides	5.33	4.51
Carbon monoxide	46.76	4.03

Table 10.4

This testing illustrates how important it is to check air/fuel mixtures at all 5 driving conditions in order to obtain an accurate assessment of how the fuel system is calibrated.

What is the ideal setting for air/ fuel mixtures? Basically, the answer is lean best power with lowest CO and HC. This will vary according to engine mechanical condition, ignition system, and fuel system design. But CO should be no higher than 0.5 percent by volume. Test 2, compared to test 5, illustrates what can result when two differently designed fuel systems are installed on the same machine (Table 10.5).

Engine condition	Engine RPM	Engine manifold vacuum	Carbon Monoxide CO (%)	Hydrocarbons HC (ppm)	Exhaust Oxygen (%)
Idle	655	18	.10	43	3.7
Max rpm	2666	14	.09	17	3.2
Part load	2000	10	.013	46	7.0
Tilt relief	2555	5	.15	26	1.6
Engine stall	1710	0	.15	39	1.4

Table 10.5

Electronic Control Devices

In order to obtain exhaust emission durability, electronic fuel management systems have been developed. These are known as "0_2 feedback control systems" and are designed to work in conjunction with the existing fuel system. These systems monitor the oxygen content in the exhaust stream using an automotive type oxygen sensor.

The voltage generated by this sensor is used to control a solenoid valve. The valve transfers a small vacuum from the mixer to the atmospheric side of the vaporizer/ regulator secondary diaphragm. This will limit diaphragm travel and, in turn, lean out the fuel mixtures. In order for this system design to exercise any mixture control authority, the base system must be set rich. As the graphic illustrates, a stoichiometric air/fuel ratio is slightly rich of lean best power. Although it is possible to biases the 0_2 switching point to the lean side of stoichiometric, these systems may not be as able to hold the part-throttle fuel mixtures as lean as it can be mechanically adjusted. However, they will keep the fuel mixtures consistent by constantly making allowances for dirty air cleaners, air temperatures, and engine conditions (Figure 10.8).

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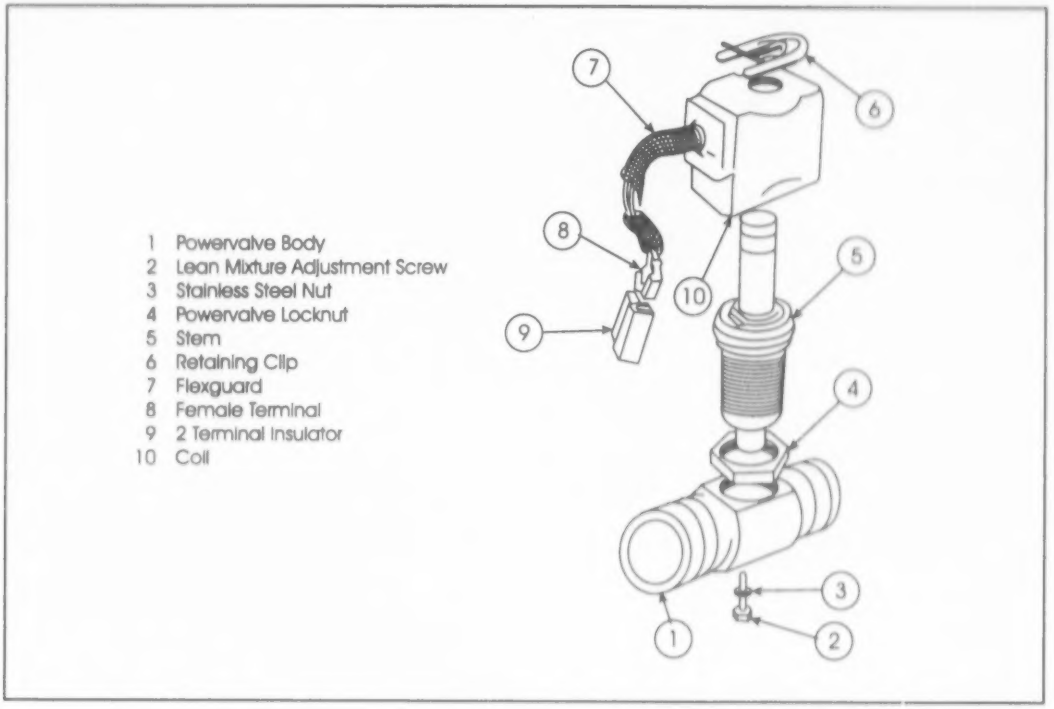

FIGURE 10.8 Power Valve Assembly

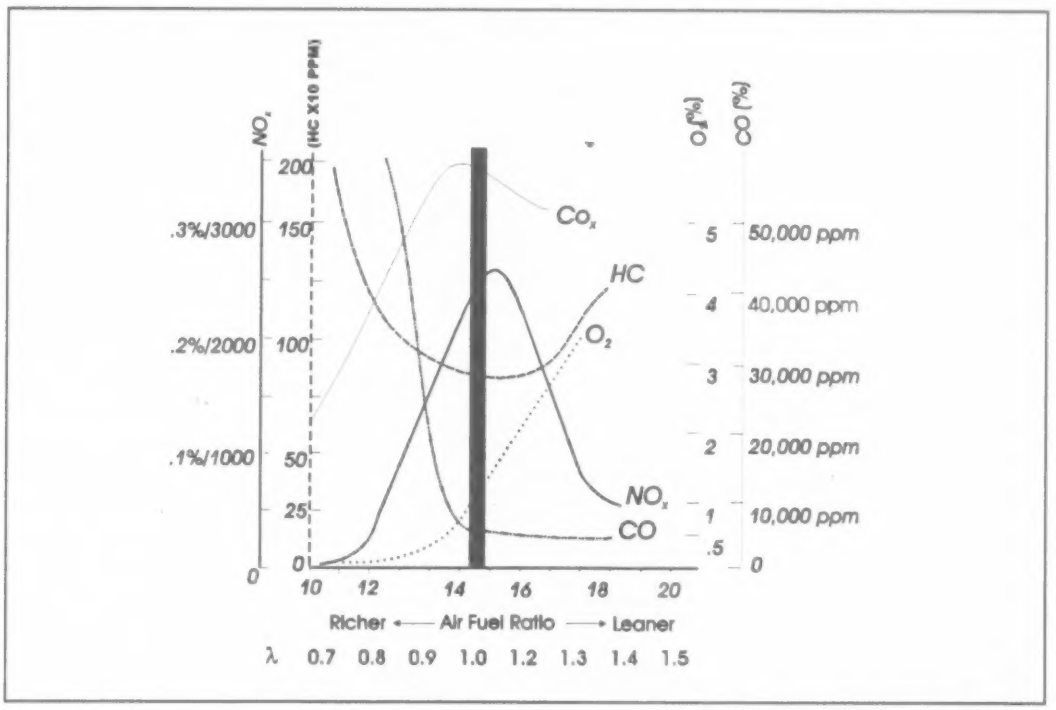

Figure 10.9 Lambda

GLOSSARY

Absolute pressure A pressure measurement that includes atmospheric pressure.

Air/fuel ratio The proportions, by weight, of air and fuel supplied for combustion.

Auto ignition Also known as knock and detonation.

Bi-fuel For the spark-ignited (Otto cycle) engine, it is a process that allows the engine to operate totally on either gasoline or an alternative fuel (normally natural gas or propane) gasoline, or an alternative backup fuel. One could use natural gas with propane as the backup fuel, or vice-versa.

Boiling point The temperature at which a fuel changes from a liquid to a vapor state.

Cetane number An indicator of the ignition quality of diesel fuels.

Density The weight of a specific hydrocarbon fuel for a volumetric measurement.

Diesel cycle An engine operating cycle in which air is heated by compression, thus igniting the air/fuel mixture.

Energy sensity The energy content of a specific hydrocarbon fuel for a volumetric measurement BTUs/Lb.

Flammability limits The minimum or maximum percentage of fuel needed in an air/fuel mixture to support combustion.
Flash point - the lowest temperature at which a fuel will give off a vapor that can be ignited by an ignition source.

Gas laws The relationship among pressure, volume, and temperature as described by Boyles, Charles, and Ideal gas laws.
Gauge pressure - a pressure measurement that excludes atmospheric pressure.

Heating value Heat release, heat of combustion; the amount of heat released during combustion of fuel as measured by weight (BTUS / Lb.).

High heat value The gross / upper heat value of a fuel before energy losses from combustion.

Knock The uncontrolled combustion of fuel in an engine caused by increased pressure and temperature after the spark occurs.

Low heat value The net / lower value of a fuel after energy losses from water vapor in the exhaust. The net heat value the engine responds to.

Mass air flow A computer control fuel management system using information from an air flow meter or a hot wire sensor.
Molecular structure The composition of hydrogen and oxygen molecules specific to each hydrocarbon.

Octane A performance measurement of a fuels anti knock characteristics.

Otto cycle The cycle of events in a four stroke, spark-ignited engine. Named for the German inventor, Dr. Nicholas Otto.

Preignition The ignition of the air/fuel mixture in a combustion chamber before the spark occurs, caused by surface ignition or auto ignition.

Speed density A computer-controlled fuel management system using engine speed and manifold vacuum.

Stoichiometric air ratio The exact air/fuel ratio required to completely combust a fuel to water and carbon dioxide.

GLOSSARY

Surface ignition The ignition of the air/fuel mixture in a combustion chamber by a hot surface rather than by a spark. To alleviate any confusion between the two processes, the dual fueling spark ignited engine is now known as bi-fuel.

Vapor density The weight of gaseous fuels in relation to air.

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Heavy Duty and Alternative Fuel Applications
Forklift and Material Handling

Suggested Agenda

Day 1	Time
Introductions	15
Pre-test	15
Need for Cleaner Burning Fuels	10
Comparison of Various Fuels to Gasoline	75
Fuel System Operation	70
Lunch	60
Propane Tanks	40
CNG Cylinders	20
Fuel System Components	160

Day 2	Time
Health and Safety	45
Refueling	30
Maintenance and Repair	80
Lunch	60
Exhaust Emissions	120
Definitions	5
Summary and Discussion	15
Post-test	40
Feedback and Evaluations	10
Fast-Breaking News	15

Daily Schedule	Time
Start	8:30 am
Break	10:15 am
Lunch	12:00 pm
Start	1:00 pm
Break	2:15 pm
End	4:30 pm

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 15

Section Title:

Introductions

Objectives:

1. Identify participants and instructor.
2. Discover common experiences and backgrounds.

Content Sequence:

1. Introduction of instructor.
2. Introduction of participants.
3. Invite students to relate their stories about forklifts and material handlers.
4. Invite students to express their needs as trainers to teach forklift and material handlers alternative fuel operation.

Media Materials:

1. Manual
2. Suggested Videos: Videos can be acquired from industry suppliers-
   Propane Sales Industry, available from the National Propane Gas Association
   CNG Sales Industry, available from the American Gas Association;
   the Propane Solution NPGA #2835.

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 15

Section Title:

Pretest

Objectives:

1. Identify participants' levels of content mastery prior to seminar presentation.

Content Sequence:

1. Pretest the participants.

Media Materials:

1. Pre-test
2. Pencils or pens

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 10

Section Title:

Introduction

Objectives:

1. Direct students to the construction of the manual and the course.
2. Introduce forklift background.

Content Sequence:

1. Discuss: content of the manual
   instructor notes (section titles, objectives, sequence, media materials)
   activity sheets
   pretests
   posttests
   transparencies
   job aids
2. Need for clean burning fuels

Media Materials:

1. Manual

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 75

Section Title:

Comparison of Various Fuels to Gasoline.

Objectives:

1. Understand differences in various types of fuels (electric, propane, and natural gas) to gasoline.
2. Identify the fuels, their properties, and their handling characteristics.

Content Sequence:

1. Identify the fuels, their properties, and their handling characteristics.
2. Describe the purposes of the fuels.
3. Demonstrate safe handling of the fuels.
4. Compare fuels by their properties.

Media Materials:

1. Manual
2. Lab 1: Understanding Fuel Vaporization.
3. Lab 2: Fuel Parameters
4. Lab 3: Fuel Chart

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 70

Section Title:

Fuel System Operation

Objectives:

1. Demonstrate the operating fundamentals of fuels systems.

Content Sequence:

1. Identify the conditions fuel is demanded by engine.
2. Discuss fuel supply actions by carburetor.
3. Discuss differences between gasoline and gaseous fuel system operation.
4. Understand operational sequences between fuel systems.

Media Materials:

1. Manual
2. Lab 4: Component Identification
3.
4. Lab 5: CNG/LPG Forklift Systems

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 40

Section Title:

Propane Tanks

Objectives:

1. Demonstrate the ability to determine the proper components for propane applications.

Content Sequence:

1. Evaluate the fuel and choose tanks, lines, hoses, valves, and fittings according to NFPA 52 and 58 Standards.
2. Decipher tank markings.

Media Materials:

1. Manual
2. Lab 4: Tank Components

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 20

Section Title:

CNG Cylinders

Objectives:

1. Demonstrate the ability to determine the proper components for CNG applications.

Content Sequence:

1. Evaluate the fuel and choose tanks, lines, hoses, valves, and fittings according to NFPA 52 and 58 Standards.
2. Decipher tank markings.

Media Materials:

1. Manual
2. Suggested Handout: Acquire the Gas Research Institute's Topical Report- Compressed Natural Gas (CNG) Cylinders: Tips for General Visual Inspection and Care (GRI-96/0426). Prepared by the Gas Research Institute, Natural Gas Vehicle Business Unit, 1331 Pennsylvania Avenue NW, Suite 730 North, Washington DC 20004-1703
3. Lab 5: Cylinder Components

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 160

Section Title:

Fuel System Components

Objectives:

1. Understand terminology related to fuel system hardware.
2. Understand the basic operation of mixers and carburetors.
3. Describe the application of mixers and carburetors in fuel systems.
4. Determine the proper application of vaporizers/regulators.

Content Sequence:

1. Describe the basic components found on all fuel systems.
2. Explain the theory of the various fuel induction systems.
3. Explain the principles of vaporizers.
4. Identify positive, negative, and atmospheric pressures.
5. Explain methods of vaporization and controls.
6. Evaluate problems associated with cracking of fuels within the vaporizer.
7. Identify and evaluate various brands of vaporizer regulators.

Media Materials:

1. Manual
2. Lab 6: Gas/air valves, disassemble, and reassemble modifications.
3. Lab 7: Disassemble and reassemble various vaporizers and regulators.

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 45

Section Title:

Health and Safety

Objectives:

1. Review previous day theory.
2. Demonstrate knowledge of fuel hazards.

Content Sequence:

1. Begin with fuel theory and discussion of day one progress.
2. Discuss the most common hazards associated with fuels.
3. Identify the health signs of contamination.
4. Describe the actions to take to aid recovery from contamination.

Media Materials:

1. Manual
2. Lab 8: Carbon Monoxide Reading

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 30

Section Title:

Refueling

Objectives:

1. Evaluate methods and hazards of refueling.

Content Sequence:

1. Explain general procedures for refueling.
2. Perform visual inspection of tanks and cylinders.
3. Demonstrate knowledge of filled tank characteristics.

Media Materials:

1. Manual
2. Lab 9: Refueling Familiarization

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 80

Section Title:

Maintenance and Repair

Objectives:

1. Determine principles of engine diagnostics.
2. Verify engine condition

Content Sequence:

1. Recognize safety requirements for gaseous fuel applications.
2. Demonstrate hose fitting.
3. Discuss ignition systems.
4. Identify regulator characteristics.
5. Demonstrate knowledge of troubleshooting

Media Materials:

1. Manual
2. Lab 10: Pressure Differential
3. Lab 11: Master Technician Training Analysis

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 120

Section Title:

Exhaust Emissions

Objectives:

1. Determine the proper compliance needed for emissions.
2. Discuss the emission requirements of inside work area and tail pipes.

Content Sequence:

1. Identify system problems (fuel or mechanical).
2. Interpret emissions in order to improve efficiency, environmental, and cost factors.

Media Materials:

1. Manual
2. Lab 12: Air/Fuel Ratios & Emissions Analyzer

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section:__5__

Section Title:

Definitions

Objectives:

1. Understand the specific terms related to alternative fuels

Content Sequence:

1. Identify terms specific to alternative fuels throughout the training session

Media Materials:

1. Manual

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 15

Section Title:

Summary and Discussion

Objectives:

1. Identify main concepts presented in this seminar.

Content Sequence:

Media Materials:

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 15

Section Title:

Posttest

Objectives:

1. Identify participants' level of content mastery after the corresponding seminar presentation.

Content Sequence:

1. Identify content areas mastered at the end of each section.
2. Compare and contrast competency areas identified by the section's pre- and posttests.

Media Materials:

1. Post-test for students
2. Post-test answers for discussion

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 10

Section Title:

Feedback and Evaluations

Objectives:

1. Elicit participants' views on this seminar.

Content Sequence:

1. Identify participants' views on this seminar presentation.
2. Identify participants' views on appropriateness and thoroughness of content.
3. Identify participants' views on usefulness of materials and supplies.

Media Materials:

1. Training session evaluation forms
2. Course completion forms

Approved by:_____ Date:_____

INSTRUCTOR NOTES

Suggested Start Time:_____
Time For This Section: 15

Section Title:

Fast-Breaking News

Objectives:

1. Outline !ate-breaking news relevant to the concepts discussed in this seminar.

Content Sequence:

Media Materials:

1. Handouts of current news related to alternative fuels
2. Responses to specific questions raised during the training session

Approved by:_____ Date:_____

ACTIVITY SHEET

1. UNDERSTANDING FUEL VAPORIZATION

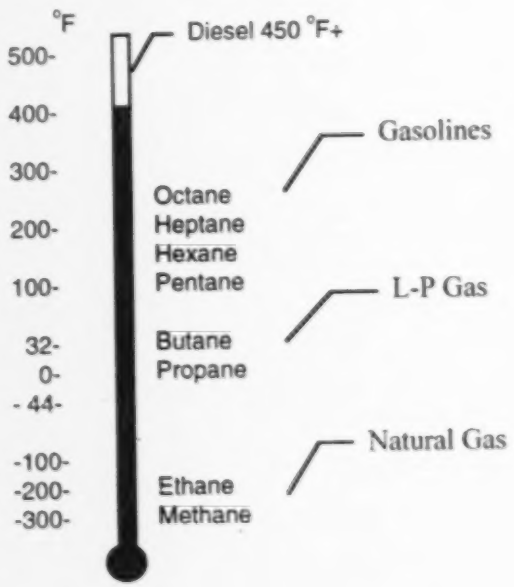
Name_____ Date_____

Objective:
To demonstrate the principles of fuel characteristics.

Equipment:
Paper and pencil. Theory room.

Safety:
When working around operating engines, make sure the exhaust gasses are properly vented. Also make sure that standard automotive safety practices are used when working with running engines. Be aware of high voltage spark plug wire location, hot manifolds, and the position of moving belts and fans. Observe all tool and laboratory practices at all times.

Procedure:
1. There is a principle advantage to gaseous fuels. An advantage is the vaporization temperature of the fuel. Examine the following boiling points of the fuels.



2. Discuss the effect of the lower boiling point of the fuel with a classmate, and answer the following questions:

3. LP gas is delivered to the carburetor in what form?

A LIQUID
B GAS.

4. Gasoline is delivered to the carburetor in what form?

A LIQUID
B GAS.

5. Natural Gas is delivered to the carburetor in what form?

A LIQUID
B GAS.

6. Fuel containers are designed to hold fuels with lower boiling points require:

A No structural changes to container
B Increased structural container strength
C Decreased structural container strength

ACTIVITY SHEET

ALTERNATIVE FUELS TRAINING

2. FUEL PARAMETERS

Name_____ Date_____

Objective:
To demonstrate the principles of fuel characteristics, parameters and their effect on engine combustion.

Equipment:
Paper and pencil. Theory room. Fuels chart.

Safety:

Procedure: Using the fuels property chart, and a pencil or pen, fill in the open spaces. Circle the effect of the fuel property on engine performance and engine emissions. If the property increases engine power output circle (+), if the property decreases engine output circle (-), if the property has no effect on engine output circle (=). If the property increases exhaust emissions circle (+), if the property decreases exhaust emissions circle (-), if the property has no effect on exhaust emissions circle (=).

Property	Gasoline	CNG	Propane
Octane Number	130	( ) Performance + - = Emissions + - =	( ) Performance + - = Emissions + - =
Boiling Point	-162	( ) Performance + - = Emissions + - =	( ) Performance + - = Emissions + - =
Autoignition Temperature	540	( ) Performance + - = Emissions + - =	( ) Performance + - = Emissions + - =
Peak Flame Temperature	1790	( ) Performance + - = Emissions + - =	( ) Performance + - = Emissions + - =
Spark Ignition Energy	0.29	( ) Performance + - = Emissions + - =	( ) Performance + - = Emissions + - =

ACTIVITY SHEET

* ALTERNATIVE FUELS TRAINING *

3. FUEL CHART

Name_____ Date_____

Objective: Familiarize participants with the properties of fuels.

Equipment:
Theory room. Fuels property chart

Safety:
To avoid eye strain, have the students stand in close proximity to the chart.

Procedure:
1. The instructor will present the information on the fuels chart to the class.
2. Use performance and engine output as demonstrations of the various properties of fuels.
3. Indicate if the power of an engine is affected by each characteristic, and if so ask the participant to determine the correct effected.
4. Indicate if the exhaust emissions are affect by each fuel characteristic, and if so, ask the participants to determine the effect that would be demonstrated if analyzed on an exhaust gas analyzer.
5. At the instructors discretion, this activity may lead to the measurement of exhaust emissions using an exhaust gas analyzer.

ACTIVITY *SHEET*

* ALTERNATIVE FUELS TRAINING *

4. COMPONENT IDENTIFICATION

Name_____ Date_____

Objective: To be able to identify components associated with alternative fuel applications.

Equipment:
Original equipment and cutaway components. More than one of each component.
LPG: tanks, valves, regulators, mixers, lines, hoses, fittings, regulation guides
Paper and pencil. CNG: cylinders, valves, regulators, mixers, lines, hoses, fittings, regulation guides.

Safety:
Cutaway components may contain sharp edges and small pieces. Handle the components with care to avoid injury.

Procedure:
1. Read the section of the training manual that deals with the components.
2. Refer to the appropriate section of the regulation guide that deals with the component.
3. Demonstrate the operation of the component verbally to the class.
4. Pass an identical component around the class so each participant may become familiar with the item.
5. Demonstrate the flow of fuel into and out of the component verbally, while pointing out the flow to the participants.
6. Pass the cutaway component around the class room.

ACTIVITY *SHEET*

* ALTERNATIVE FUELS TRAINING *

5. CNG / LPG FORKLIFT SYSTEM POSTER

Name_____ Date_____

Objective: Familiarize participants with the components of the CNG/LPG forklift.

Equipment:
Theory room. CNG/LPG forklift overhead chart from figures 3.3 and 3.4 in the manual

Safety:
To avoid eye strain, have the students stand in close proximity to the chart.

Procedure:
1. The instructor will present the information on the forklift chart to the class.
2. Use performance and engine output as demonstrations of the various components of CNG/LPG systems. Coordinate the explanation with the equivalent gasoline component.
3. Indicate if the power of an engine is affected by each component, and if so ask the participant to determine the correct effect in comparison to the gasoline equivalent.
4. Indicate if the exhaust emissions are affect by each component, and if so, ask the participants to determine the effect that would be demonstrated if changes to the component could be analyzed on an exhaust analyzer.
5. At the instructors discretion, this activity may lead to the measurement of exhaust emissions using an exhaust gas analyzer while components are adjusted.

ACTIVITY SHEET

* ALTERNATIVE FUELS TRAINING *

6. TANK COMPONENTS

Name_____ Date_____

Objective: To be able to identify propane tank components associated with alternative fuel applications.

Equipment:
Original equipment and cutaway with components. More than one of each component.
LPG tank with the valves, regulators, mixers, lines, hoses, fittings, fill connectors installed and removable by hand. Tank regulation guides
Original equipment and cutaway with components. More than one of each component.
CNG: cylinders, valves, regulators, mixers, lines, hoses, fittings, regulation guides.

Safety:
Cutaway components may contain sharp edges and small pieces. Handle the components with care to avoid injury.

Procedure:
1. Read the section of the training manual that deals with the components.
2. Refer to the appropriate section of the regulation guide that deals with the component.
3. Demonstrate the operation of the component verbally to the class.
4. Pass an identical component around the class so each participant may become familiar with the item.
5. Demonstrate the flow of fuel into and out of the component verbally, while pointing out the flow to the participants.
6. Pass the cutaway component around the class room.

ACTIVITY SHEET

* ALTERNATIVE FUELS TRAINING *

7. CYLINDER COMPONENTS

Name_____ Date_____

Objective: To be able to identify CNG Cylinder components associated with alternative fuel applications.

Equipment:
Original equipment and cutaway with components. More than one of each component.
Original equipment and cutaway with components. More than one of each component.
CNG: cylinders, valves, regulators, mixers, lines, hoses, fittings, regulation guides.

Safety:
Cutaway components may contain sharp edges and small pieces. Handle the components with care to avoid injury.

Procedure:
1. Read the section of the training manual that deals with the components.
2. Refer to the appropriate section of the regulation guide that deals with the component.
3. Demonstrate the operation of the component verbally to the class.
4. Pass an identical component around the class so each participant may become familiar with the item.
5. Demonstrate the flow of fuel into and out of the component verbally, while pointing out the flow to the participants.
6. Pass the cutaway component around the class room.

ACTIVITY *SHEET*

ALTERNATIVE FUELS TRAINING

8. GAS/AIR VALVE

Name_____ Date_____

Objective: Demonstrate proficiency with specific maintenance procedures

Equipment:
Lab. Gas/air valve for propane and natural gas. OEM manual. Hand tools.

Safety:
Components contain small pieces that may become lost. Carefully control component pieces.

Procedure:
1. Familiarize students with the fundamental operation of the component.
2. Locate the section in the OEM dealing with the inspection, overhaul, and maintenance of the component.
3. Follow the OEM procedures to inspect the component.
4. Follow the OEM procedures to overhaul and repair the component.
5. Follow the OEM procedures to put the component back together.'

ACTIVITY SHEET

* ALTERNATIVE FUELS TRAINING *

9. REGULATOR DISASSEMBLY

Name_____ Date_____

Objective: Demonstrate proficiency with regulator maintenance procedures

Equipment:
Lab. First (and second) stage regulator for propane and natural gas. OEM regulator maintenance manual. Hand tools.

Safety:
Components contain small pieces that may become lost. Carefully control component pieces. Springs exert pressure and may eject from components, wear proper eye protection.

Procedure:

1. Familiarize students with the fundamental operation of the regulator prior to continuing with this activity.
2. Locate the section in the OEM manual dealing with the inspection, overhaul, and maintenance of the regulator.
3. Follow the OEM procedures to inspect the regulator.
4. Follow the OEM procedures to overhaul and repair the regulator.
5. Follow the OEM procedures to put the regulator back together.'
6. Have the instructor check the progress of the activity. _____
7. Follow the OEM procedures to set the adjustment of the regulator. (Instructor Initial)
8. Set the adjustment to the OEM manual specification.

10. CARBON MONOXIDE READING

Name_____ Date_____

Objective:
To demonstrate the proper operation of a carbon monoxide tester to measure the recommended safe levels of carbon monoxide exposure.

Equipment:
Carbon monoxide tester and operating instructions. Appropriate carbon monoxide gas source (CO bottle, CO collection bag). A scale model of an enclosed industrial warehouse (cardboard box with clear plastic windows, fish tank, or clear plexi-glass box). A time piece to measure passing time.

Safety:
When working around carbon monoxide sources, make sure the area gasses are vented properly. Also make sure that standard automotive safety practices are used when working with running engines. Be aware of high voltage spark plug wire location, hot manifolds, and the position of moving belts and fans. Observe all tool and laboratory practices at all times.

Procedure:
1. Confirm the carbon monoxide tester calibration, refer to the operating manual for calibration instructions.

2. The carbon monoxide tested should contain a warning alarm that goes off when unsafe level of carbon monoxide are detected. Ensure the carbon monoxide alarm buzzer functions.

3. Refer to the carbon monoxide users manual. What are the visual and audio responses given to indicate the level of carbon monoxide?

Exposure	Visual	Audio
9 ppm (0.0009%)		
50 ppm (0.005%)		
200 ppm (0.02%)		
400 ppm (0.04%)		
800 ppm (0.08%)		
1,600 ppm (0.16%)		
3,200 ppm (0.32%)		
6,400 ppm (0.64%)		
12,800 ppm (1.28%)		

4. The carbon monoxide tester for forklift maintenance and repair will help the technician be aware of the CO present. What is the CO setting that is usually the goal for engine exhaust calibration? _____.

5. This setting may be acceptable for engine tune-ups, but this reading may cause concern for industrial safety and health regulators. Their concern may be realized by describing what happens to the body at other levels of CO exposure:

Exposure	Maximum Allowable Exposure and Effect
9 ppm (0.0009%)	Short-term exposure in living areas
50 ppm (0.005%)	For continuous exposure in any 8-hour period
200 ppm (0.02%)	Headaches, fatigue, dizziness, and nausea after 2-3 hours
400 ppm (0.04%)	In flue gas. After 2-3 hours frontal headaches. Life threatening after 3-hours.
800 ppm (0.08%)	Dizziness, nausea and convulsions within 45 minutes. Death within 1-hour.
1,600 ppm (0.16%)	Headaches, dizziness and nausea within 20 minutes. Death within 1-hour
3,200 ppm (0.32%)	Headache, dizziness and nausea within 5-10 minutes. Death within 30 minutes.
6,400 ppm (0.64%)	Headache, dizziness and nausea within 1-2 minutes. Death within 10-15 minutes
12,800 ppm (1.28%)	Death within 1-3 minutes.

Demonstration:

1. Demonstrate carbon monoxide readings in a simulated industrial setting.

2. Place the demonstration scale model in a well ventilated area.

3. Place the carbon monoxide meter in the model with the display facing the clear window. The display reading should be clearly visible through the clear window.

4. Close the scale model and record the carbon monoxide reading. _____.

5. Attach a carbon monoxide source to the demonstration scale model so CO gas can be released to fill the inside of the model.

6. Record the time. Slowly add carbon monoxide to the interior of the scale model.

Exposure	Time
9 ppm (0.0009%)	_____
50 ppm (0.005%)	_____
200 ppm (0.02%)	_____
400 ppm (0.04%)	_____
800 ppm (0.08%)	_____
1,600 ppm (0.16%)	_____
3,200 ppm (0.32%)	_____
6,400 ppm (0.64%)	_____
12,800 ppm (1.28%)	_____

ACTIVITY *SHEET*

* ALTERNATIVE FUELS TRAINING *

11. REFUELING FAMILIARIZATION

Name_____ Date_____

Objective: To demonstrate the refueling options and capabilities of alternative fuel forklifts and material handlers.

Equipment:
Shop. Forklift or material handler that operates on an alternative fuel.

Safety:
LPG tanks can be heavy, use proper back support when lifting and moving LPG tanks. Gases under pressure can cause serious injury, use caution when connecting and disconnecting components from fittings.

Procedure:
1. Inspect the tank or cylinder prior to filling.
2. Check to ensure the filling equipment is in proper operating condition prior to using.
3. Check the tank or cylinder fuel level. Do not overfill.
4. Remove fill receptacle protective cap from the tank or cylinder.
5. Remove fill hose from storage and connect to the tank or cylinder fill connection.
6. Open LPG fill valve or vent valve (and start the pump if necessary).
7. Open valve on the end of the fill hose slowly to prevent rapid pressure changes.
8. Do not overfill container. Monitor fuel level in the tank or cylinder.
9. When full, close the container fill valve (and vent valve, shut off pump if necessary).
10. Carefully disconnect fill hose. Pressure may be trapped in the connection, avoid contact with the escaping gas.
11. Replace the fill receptacle protective cap from the tank or cylinder.
12. Check for leaks after replacing the protective cap.
13. Store the fill hose.

ACTIVITY *SHEET*

12. PRESSURE DIFFERENTIAL

Name_____ Date_____

Objective:
To demonstrate the proper diagnosis of a fuel delivery system using pressure gauges.

Equipment:
0-5000 psi pressure gauge, 0-500 psi pressure gauge. Basic hand tools. Service manual. Safety equipment. Vacuum gauge or manometer set.

Safety:
When working around operating engines, make sure the exhaust gasses are properly vented. Also make sure that standard automotive safety practices are used when working with running engines. Be aware of high voltage spark plug wire location, hot manifolds, and the position of moving belts and fans. Observe all tool and laboratory practices at all times.

CAUTION: High pressure systems must be isolated and relieved of pressure before entering the system.

Procedure:
A vehicle would not run on a gaseous fuel. The customer took it to be serviced. The technician found no faults in the electrical system and suspected a gaseous fuel delivery problem. Follow these steps:

1. Verify the problem.
2. Refer to the manufacturer's service manual and conversion system manual.
3. Apply the suggested corrective actions from the manaul.
4. Did the procedure fix the problem? YES NO
5. If the equipment does not start, what is the next step? List the possible steps.

_____

_____

_____

6. Check the pressure downstream of the (first) regulator.
7. Analyze pressure to manufacturer's specification.
8. Isolate pressure by determining if it is within the recommended range.
9. If a pressure discrepancy exists. Identify possible causes.
10. Remove high pressure and low pressure lines from the regulator and check for blockage.

ACTIVITY *SHEET*

* ALTERNATIVE FUELS TRAINING *

13. MASTER TECHNICIAN TRAINING ANALYSIS

Name_____ Date_____ _____

Objective:
To demonstrate the proper application of training methods, using peer teaching to transfer knowledge through an activity designed to help the technician learn-by-doing.

Equipment:
Shop area. Select problem to be resolved.

Safety:
When working around operating engines, make sure the exhaust gasses are properly vented. Also make sure that standard automotive safety practices are used when working with running engines. Be aware of high voltage spark plug wire location, hot manifolds, and the position of moving belts and fans. Observe all tool and laboratory practices at all times.

Procedure:

1. The instructor will first model a sample demonstration of proper and improper methods for training individuals in diagnostic methods.

2. Enter the shop area and attend a mock teaching lesson being conducted by a team member. The lesson will be based on a chosen problem, wither from the class lessons or from individual experiences.

3. The students will then attempt to apply the methods for training other students. The student-trainer will demonstrate using the experience as an example for training.

ACTIVITY *SHEET*

* ALTERNATIVE FUELS TRAINING *

14. AIR/FUEL RATIOS & EMISSIONS ANALYZER

Name_____ Date_____

Objective:
To demonstrate the proper operation of the exhaust gas analyzer using material handling equipment, using propane and natural gas engine exhaust as the emissions sample.

Equipment:
Propane fueled material handler. Natural gas fueled material handler. Exhaust gas analyzer.

Safety:
When working around operating engines, make sure the exhaust gasses are properly vented. Also make sure that standard automotive safety practices are used when working with running engines. Be aware of high voltage spark plug wire location, hot manifolds, and the position of moving belts and fans. Observe all tool and laboratory practices at all times.

Procedure:
1. Confirm the gas engine analyzer is connected properly, operating properly and set-sup correctly for the vehicle being tested.

2. List the tools and equipment need to perform an emissions test.
_____
_____
_____

3. Describe the natural gas/air mixing system used on the material handler being tested.
_____
_____
_____

4. List the adjustments that are possible (if any) for the gas/air mixing system.
_____
_____
_____

5. Start the vehicle engine and record the stabilized idle measurement. Make the following adjustments and note the changes in the exhaust gas. Record these measurements in the appropriate spaces provided on the activity sheet.

6. Take reading from analyzer with engine at idle.

7. Place engine at maximum governed, no-load RPM: take reading from analyzer.
8. Prepare forklift for part-load.
   - Chock wheels.
   - Apply parking brake
   - Bring engine to 2,000 RPM.
   - Attain approximately 10" Hg manifold vacuum by applying tilt relief load.
   - Take reading from analyzer
   -
9. Prepare forklift for full load, engine stall.
   - Chock wheels.
   - Apply parking brake.
   - Place machine in drive.
   - Apply full load to engine, monitor engine analyzer, take reading at stall.
   -
10. Shutoff forklift, after taking readings.

11. Were the readings satisfactory? _____

_____

NATURAL GAS					
Engine Condition	Engine RPM	Engine Manifold Vacuum	Carbon Monoxide (%)	Hydrocarbons (ppm)	Exhaust Oxygen (%)
Idle					
Max rpm					
Part Load					
Tilt Relief					
Engine Stall					

PROPANE					
Engine Condition	Engine RPM	Engine Manifold Vacuum	Carbon Monoxide (%)	Hydrocarbons (ppm)	Exhaust Oxygen (%)
Idle					
Max rpm					
Part Load					
Tilt Relief					
Engine Stall					

GASOLINE					
Engine Condition	Engine RPM	Engine Manifold Vacuum	Carbon Monoxide (%)	Hydrocarbons (ppm)	Exhaust Oxygen (%)
Idle					
Max rpm					
Part Load					
Tilt Relief					
Engine Stall					

Pre Test*sheet*

Pre Test Sheet **Name:**

Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

1. Which of the following statements is true?
   a. Gasoline burns cleaner than natural gas
   b. Gasoline has lower emission levels than natural gas
   c. Natural gas contaminates engine oil less than gasoline
   d. Gasoline allows for a longer engine life than natural gas

2. Which of the following statements are true?
   a. Propane, unlike gasoline, is a hydrocarbon
   b. Propane is highly volatile
   c. Gasoline is highly volatile
   d. Under normal atmospheric conditions, propane remains in a liquid state

3. Which are characteristics of propane?
   a. Is a compound of carbon and hydrogen
   b. Remains in a vapor state under normal atmospheric conditions
   c. It is naturally a colorless, odorless gas
   d. All of these

4. Which is *not* characteristic of natural gas?
   d. Has been a transportation fuel for more than 50 years
   e. United States has an abundant supply
   f. Has an extensive distribution system to residences
   g. High cost

5. How often are DOT tanks recertified?
   e. A visual inspection after the first twelve years
   f. A visual inspection after the first seven years
   g. A visual inspection after the first three years
   h. None of these

6. Which are characteristics of ASME name plates?
   f. Permanently attached on the tank
   g. State the year of manufacture
   h. Made of stainless steel
   i. All of these

Pre Test*sheet*

Pre Test Sheet **Name:** _____
Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

7. Which valves and apparatus apply to DOT and ASME tanks?
   j. Pressure relief valve
   k. Fill valve
   l. 80 percent liquid level gauge
   m. All of these

8. Which of the following lock offs contain a microswitch?
   h. Electrically activated fuel lock
   i. Vacuum activated fuel lock
   j. Oil pressure activated fuel lock
   k. None of these

9. A mixer in a propane system:
   i. Mixes oil and air
   j. Mixes fuel and oil
   k. Mixes air and fuel
   l. None of these

10. Why do some primary regulators have two springs?
    j. Allows for constant pressure
    k. Allows continuous movement
    l. Allows pressure differential
    m. All of these

11. When starting an engine in cold temperatures, the vaporizer/regulator will freeze if _____ flows directly through it.
    a. Oil
    b. Water
    c. Fuel
    d. Bi-products

Pre Test*sheet*

Pre Test Sheet **Name:** _____
Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

12. When an engine runs at a higher temperature, which of the following occurs?
    l. Cracking at heavy ends
    m. Formation of sludge
    n. Expansion of gas
    o. All of these

13. Which occurs with higher octane levels?
    m. Fuel burns faster
    n. Fuel burns slower
    o. Octane level does not determine speed of fuel burn
    p. None of these

14. A poor ignition system can cause which of the following?
    n. Misfiring
    o. Hard starting
    p. Reduced fuel economy
    q. All of these

15. It takes ____ F degrees to ignite gasoline and ____F degrees to ignite propane.
    o. 950; 850
    p. 750; 850
    q. 850; 950
    r. 850; 750

16. What is a step in servicing an engine with a vacuum lockoff?
    p. Squeeze vacuum hose and listen for RPM change
    q. Check gas pressure
    r. Remove vapor locks
    s. Observe pressure reading

17. If a 'no start' condition exists, what should be tested first?
    q. Spark plug
    r. Faulty wires
    s. Vacuum leaks
    t. Loose connection

Pre Test*sheet*

Pre Test Sheet **Name:**
Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

18. Which of the following describes octane?
    u. A cycle of events
    v. A performance measurement
    w. Air fuel ratio
    x. Weight of fuel

19. If a gasoline spark plug gap is .035, a propane spark plug gap is what width?
    s. .015
    t. .025
    u. .035
    v. .045

20. Which of the following is mechanically advanced by increased RPM?
    t. Initial timing
    u. Flyweight curve
    v. Vacuum advance system
    w. None of these

21. How many KV may be required to cross a worn spark plug gap?
    a. 10 KV
    b. 20 KV
    c. 30 KV
    d. 40 KV

22. How does a control valve lean gas mixture?
    v. Opening and closing a mixture valve
    w. Keeping a mixture valve open
    x. Keeping a mixture valve closed
    y. None of these

23. Which of the following are sources of carbon monoxide?
    w. Internal combustion engines
    x. Furnaces
    y. Cigarette smoke
    z. All of these

Pre Test*sheet*

Pre Test Sheet **Name:**
Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

24. What might cause a 3% to 8% CO emission?
    aa. Out of tune engine
    bb. Defective carburetor
    cc. Dirty air filter
    dd. All of these

25. Which of the following are symptoms of carbon monoxide poisoning?
    y. Headaches
    z. Dizziness
    aa. Fatigue
    bb. All of these

26. Which is prohibited around fueling operations?
    z. Smoking and open flames
    aa. Sources of ignition
    bb. Passengers
    cc. All of these

27. What is the first step in performing fueling operations?
    aa. The cylinder should be weighed
    bb. The cylinder should be inspected
    cc. The liquid outlet valve and bypass return valve should be opened
    dd. The protective plug in the fill valve should be removed

28. The content of _____ in gasoline, propane, and natural gas changes the gap size necessary for the spark to bridge.
    a. Hydrogen
    b. Oxygen
    c. Carbon
    d. None of these

Pre Test*sheet*

Pre Test Sheet **Name:**
Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

29. A time-fill CNG tank takes how long to fill?
    cc. Up to 5 minutes
    dd. Up to 7 hours
    ee. Up to 24 hours
    ff. None of these

30. A fast-fill CNG tank takes how long to fill?
    dd. Up to 5 minutes
    ee. Up to 7 hours
    ff. Up to 24 hours
    gg. None of these

31. Fittings made of _____ must not be used to carry liquid to the fuel lock.
    ee. Steel
    ff. Brass
    gg. Copper
    hh. Cast iron

32. High pressure hose has a working pressure of ___ and a burst pressure of ___.
    ff. 200 psi; 1200 psi
    gg. 750 psi; 1550 psi
    hh. 350 psi; 1750 psi
    ii. None of these

33. When installing hose ends, the proper length should be marked on the _____.
    gg. Engine
    hh. Frame
    ii. Hose
    jj. All of these

34. What is the purpose of electronic feedback systems?
    hh. Control air fuel mixture
    ii. Identify dangerous emissions
    jj. Improve exhaust emissions
    kk. All of these

Post Test *sheet*

Post Test Sheet **Name:** ___

Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

1. Which of the following statements is true?
   a. Gasoline burns cleaner than natural gas
   b. Gasoline has lower emission levels than natural gas
   c. Natural gas contaminates engine oil less than gasoline
   d. Gasoline allows for a longer engine life than natural gas

2. Which of the following statements are true?
   a. Propane, unlike gasoline, is a hydrocarbon
   b. Propane is highly volatile
   c. Gasoline is highly volatile
   d. Under normal atmospheric conditions, propane remains in a liquid state

3. Which are characteristics of propane?
   a. Is a compound of carbon and hydrogen
   b. Remains in a vapor state under normal atmospheric conditions
   c. It is naturally a colorless, odorless gas
   d. All of these

4. Which is *not* characteristic of natural gas?
   d. Has been a transportation fuel for more than 50 years
   e. United States has an abundant supply
   f. Has an extensive distribution system to residences
   g. High cost

5. How often are DOT tanks recertified?
   e. A visual inspection after the first twelve years
   f. A visual inspection after the first seven years
   g. A visual inspection after the first three years
   h. None of these

6. Which are characteristics of ASME name plates?
   f. Permanently attached on the tank
   g. State the year of manufacture
   h. Made of stainless steel
   i. All of these

Post Test *sheet*

Post Test Sheet **Name:** ___
Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

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   j. Pressure relief valve
   k. Fill valve
   l. 80 percent liquid level gauge
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8. Which of the following lock offs contain a microswitch?
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   i. Vacuum activated fuel lock
   j. Oil pressure activated fuel lock
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9. A mixer in a propane system:
   i. Mixes oil and air
   j. Mixes fuel and oil
   k. Mixes air and fuel
   l. None of these

10. Why do some primary regulators have two springs?
    j. Allows for constant pressure
    k. Allows continuous movement
    l. Allows pressure differential
    m. All of these

11. When starting an engine in cold temperatures, the vaporizer/regulator will freeze if _____ flows directly through it.
    a. Oil
    b. Water
    c. Fuel
    d. Bi-products

Post Test *sheet*

Post Test Sheet **Name: ___**
Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

12. When an engine runs at a higher temperature, which of the following occurs?
    l. Cracking at heavy ends
    m. Formation of sludge
    n. Expansion of gas
    o. All of these

13. Which occurs with higher octane levels?
    m. Fuel burns faster
    n. Fuel burns slower
    o. Octane level does not determine speed of fuel burn
    p. None of these

14. A poor ignition system can cause which of the following?
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    o. Hard starting
    p. Reduced fuel economy
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    p. 750; 850
    q. 850; 950
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    p. Squeeze vacuum hose and listen for RPM change
    q. Check gas pressure
    r. Remove vapor locks
    s. Observe pressure reading

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    s. Vacuum leaks
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Post Test *sheet*

Post Test Sheet **Name:** ___

Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

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    v. A performance measurement
    w. Air fuel ratio
    x. Weight of fuel

19. If a gasoline spark plug gap is .035, a propane spark plug gap is what width?
    s. .015
    t. .025
    u. .035
    v. .045

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Post Test *sheet*

Post Test Sheet **Name: ___**

Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

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Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

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Answer *sheet*

Test Answer Sheet **Name:** _____

Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

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1. Which valves and apparatus apply to DOT and ASME tanks?
   g. Pressure relief valve

Answer *sheet*

Test Answer Sheet **Name:** _____

Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

h. Fill valve
i. 80 percent liquid level gauge
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    n. Expansion of gas

Answer *sheet*

Test Answer Sheet **Name:** _____

Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

o. **All of these ***

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    p. None of these

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Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

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    t. **.025 ***
    u. .035
    v. .045

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    y. None of these

23. Which of the following are sources of carbon monoxide?
    w. Internal combustion engines
    x. Furnaces
    y. Cigarette smoke
    z. **All of these ***

1. What might cause a 3% to 8% CO emission?
    x. Out of tune engine
    y. Defective carburetor
    z. Dirty air filter
    aa. **All of these ***

25. Which of the following are symptoms of carbon monoxide poisoning?
    y. Headaches

Answer *sheet*

Test Answer Sheet **Name:** _____

Heavy Duty and Industrial Alternative Applications:
Forklift and Material Handling

z. Dizziness
aa. Fatigue
bb. **All of these ***

26. Which is prohibited around fueling operations?
z. Smoking and open flames
aa. Sources of ignition
bb. Passengers
cc. **All of these ***

27. What is the first step in performing fueling operations?
aa. The cylinder should be weighed
bb. **The cylinder should be inspected ***
cc. The liquid outlet valve and bypass return valve should be opened
dd. The protective plug in the fill valve should be removed

28. The content of _____ in gasoline, propane, and natural gas changes the gap size necessary for the spark to bridge.
a. Hydrogen
b. Oxygen
c. **Carbon ***
d. None of these

29. A time-fill CNG tank takes how long to fill?
cc. Up to 5 minutes
dd. Up to 7 hours *
ee. Up to 24 hours
ff. None of these

30. A fast-fill CNG tank takes how long to fill?
dd. Up to 5 minutes *
ee. Up to 7 hours
ff. Up to 24 hours

Answer *sheet*

Test Answer Sheet **Name:** _____

Heavy Duty and Industrial Alternative Applications:
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gg. None of these

31. Fittings made of _____ must not be used to carry liquid to the fuel lock.
    ee. Steel
    ff. Brass
    gg. Copper
    hh. Cast iron *

32. High pressure hose has a working pressure of ___ and a burst pressure of ___.
    ff. 200 psi; 1200 psi
    gg. 750 psi; 1550 psi
    hh. 350 psi; 1750 psi*
    ii. None of these

33. When installing hose ends, the proper length should be marked on the _____.
    gg. Engine
    hh. Frame
    ii. Hose *
    jj. All of these

34. What is the purpose of electronic feedback systems?
    hh. Control air fuel mixture
    ii. Identify dangerous emissions
    jj. Improve exhaust emissions
    kk. All of these *